id = 00

The id of this definition is 00. Because the id is in the range of 00 to 09, the scan tool will execute this definition immediately once entered successfully.

length = 2E

The length ($2E = 46 decimal) indicates the number of characters in the definition, including the length field and the DSV field. It is checked for data entry accuracy.

type = 24

This is an SAE J1979 type definition. The first byte of the given transmit field will just be the SAE J1979 mode value. The rest of the transmit field will be defined by the mode value. The header for the transmit message is defined by the interface currently being used. The receive filter is defined by the actual transmit message header.

transmit field = 0101

This is a mode 01 SAE J1979 request message. A second byte, the PID, is defined for mode 01 request messages. The PID value is 01.

Receive filter field = <null>

The receive filter will be the default defined by the definition type and the actual transmit message header.

Received data processing field = 208651982420826120827120828l

20	ASCII code for 1 blank.
8651	Display bytes as unsigned decimal, field starts at byte 5, and is 1 byte in size. Byte 5 of the received response message is SAE J1979 response data byte 3, which is the number of emission-related powertrain diagnostic trouble codes.
9824	Display standard text $24. This is "DTC."
20	Same as above.
8261	Display bytes as bits, field starts at byte 6 and is 1 byte in size. Byte 6 of the received response message is SAE J1979 response data byte 4, which is the evaluation/Mil status bits.
20	Same as above.
8271	Same as 8261 above, except this is for SAE J1979 response data byte 5, which is evaluation support bits.
20	Same as above.

8281	Same as above, except this is for SAE J1979 response data byte 6, which is the evaluation status bits.
DSV = 48	This is the DSV value for this definition.

The Engineering Society For Advancing Mobility Land Sea Air and Space®
INTERNATIONAL
400 Commonwealth Drive, Warrendale, PA 15096-0001

SURFACE VEHICLE STANDARD

SAE J1850 | REV. MAY94

Issued 1988-11
Revised 1994-05-02

Superseding J1850 FEB94

Submitted for recognition as an American National Standard

CLASS B DATA COMMUNICATIONS NETWORK INTERFACE

TABLE OF CONTENTS

1. Scope 4
1.1 Objectives 4

2. References 5
2.1 Applicable Documents 5
2.1.1 SAE Publications 5
2.1.2 CISPR Publication 5
2.1.3 ISO Publications 5
2.2 Related Publication 5
2.2.1 SAE Publication 5
2.3 Definitions 5
2.4 Abbreviations/Acronyms 7

3. Description of the Architecture 7
3.1 General 7
3.2 Network Topology 7
3.2.1 Data Bus Topology 7
3.2.2 Data Bus Control 8
3.3 References to the OSI Model 8
3.3.1 Application Layer 8
3.3.2 Data Link Layer 8
3.3.3 Physical Layer 8
3.4 Network Implementation 8

4. Application Layer Details 8
4.1 Normal Vehicle Operation (Down the Road) Messages 8
4.2 Diagnostic Messages 11
4.2.1 Diagnostic Parametric Data 11
4.2.2 Diagnostic Malfunction Codes 11
4.3 Frame Filtering 11

SAE Technical Standards Board Rules provide that: "This report is published by SAE to advance the state of technical and engineering sciences. The use of this report is entirely voluntary, and its applicability and suitability for any particular use, including any patent infringement arising therefrom, is the sole responsibility of the user."

SAE reviews each technical report at least every five years at which time it may be reaffirmed, revised, or cancelled. SAE invites your written comments and suggestions.

Copyright 1994 Society of Automotive Engineers, Inc.
All rights reserved.

OMEGA EXHIBIT

TABLE OF CONTENTS (Continued)

5. Data Link Layer Details 11
5.1 Addressing Strategy 11
5.1.1 Physical Addressing 11
5.1.2 Functional Addressing 11
5.2 Network Access and Data Synchronization 12
5.2.1 Full Message Buffering 12
5.2.2 Byte Buffering 12
5.3 Network Elements and Structure 12
5.3.1 Frame Elements 12
5.3.2 Bit Ordering 12
5.3.3 Maximum Frame Length 12
5.3.4 Function of SOF, EOD, EOF, IFS, NB, and BRK 12
5.3.4.1 Start of Frame (SOF) 13
5.3.4.2 End of Data (EOD) 13
5.3.4.3 End of Frame (EOF) 13
5.3.4.4 Inter-Frame Separation (IFS) 13
5.3.4.5 Normalization Bit (NB) 13
5.3.4.6 Break (BRK) 13
5.3.5 Idle Bus (Idle) 13
5.3.6 Data Byte(s) 13
5.3.7 In-Frame Response (IFR) 13
5.3.7.1 Normalization Bit 15
5.4 Error Detection 15
5.4.1 Cyclic Redundancy Check (CRC) 15
5.4.2 Frame/Message Length 16
5.4.3 Out-of-Range 16
5.4.4 Concept of Valid/Invalid Bit/Symbol Detection 18
5.4.4.1 Invalid Bit Detection 18
5.4.4.2 Invalid Frame Structure Detection 18
5.5 Error Response 18
5.5.1 Transmit 18
5.5.2 Receive 18

6. Physical Layer Details 18
6.1 Physical Layer Media 18
6.1.1 Single Wire 18
6.1.2 Dual Wires 18
6.1.3 Routing 18
6.2 Unit Load Specifications 18
6.3 Maximum Number of Nodes 19
6.4 Maximum Network Length 19
6.4.1 On-Vehicle/Off-Vehicle 19
6.5 Media Characteristics 19
6.6 Data Bit/Symbol Definition/Detection 19
6.6.1 Pulse Width Modulation (PWM) 19
6.6.1.1 The One "1" and Zero "0" Bits 19
6.6.1.2 Start of Frame (SOF) 20
6.6.1.3 End of Data (EOD) 21
6.6.1.4 End of Frame (EOF) 21

TABLE OF CONTENTS (Continued)

6.6.1.5 Inter-Frame Separation (IFS) . . . 22
6.6.1.6 Break (BRK) . . . 22
6.6.1.7 Idle Bus (Idle) . . . 22
6.6.1.8 PWM Symbol Timing Requirements . . . 23
6.6.2 Variable Pulse Width Modulation . . . 23
6.6.2.1 The One "1" and Zero "0" Bits . . . 23
6.6.2.2 Start Of Frame (SOF) . . . 23
6.6.2.3 End Of Data (EOD) . . . 24
6.6.2.4 End of Frame (EOF) . . . 24
6.6.2.5 In-Frame Response Byte(s)/Normalization Bit . . . 24
6.6.2.6 Inter-Frame Separation (IFS) . . . 25
6.6.2.7 Break (BRK) . . . 25
6.6.2.8 Idle Bus (Idle) . . . 25
6.6.2.9 VPW Symbol Timing Requirements . . . 26
6.7 Contention/Arbitration/Priority . . . 26
6.7.1 Contention Detection . . . 26
6.7.2 Bit-by-Bit Arbitration . . . 27
6.7.3 Arbitration Area . . . 27
6.7.4 Frame Priority . . . 27
6.8 Node Wake-Up Via Physical Layer . . . 28
6.8.1 Network Media . . . 29
6.8.1.1 Unbiased Network . . . 29
6.8.1.2 Biased Network . . . 29
6.8.2 Individual Nodes . . . 29
6.8.2.1 Unpowered Node . . . 29
6.8.2.2 Sleeping Node . . . 29
6.8.2.3 Awake/Operational . . . 29
6.9 Physical Layer Fault Considerations . . . 29
6.9.1 Required Fault Tolerant Modes . . . 29
6.9.2 Optional Fault Tolerant Modes . . . 30
6.10 EMC Requirements . . . 30

7. Parameters . . . 31
7.1 Application Layer . . . 31
7.2 Data Link Layer . . . 31
7.2.1 Pulse Width Modulation (PWM) at 41.6 Kbps . . . 31
7.2.2 Variable Pulse Width (VPW) at 10.4 Kbps . . . 31
7.3 Physical Layer . . . 31
7.3.1 General Network Requirements . . . 32
7.3.2 Pulse Width Modulation (PWM) . . . 32
7.3.2.1 PWM Timing Requirements . . . 32
7.3.2.2 PWM DC Parameters . . . 34
7.3.3 Variable Pulse Width Modulation (VPW) . . . 35
7.3.3.1 VPW Timing Requirements . . . 35
7.3.3.2 VPW DC Parameters . . . 35

8. Notes . . . 36
8.1 Marginal Indicia . . . 36

TABLE OF CONTENTS (Continued)

APPENDIX A - CHECKLIST OF APPLICATION-SPECIFIC FEATURES 37

APPENDIX B - I/O EMC TEST PLAN 39

APPENDIX C - VPW WAVEFORM ANALYSIS 42

APPENDIX D - PWM WAVEFORM ANALYSIS 46

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.

(R) 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.

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.

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.

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.

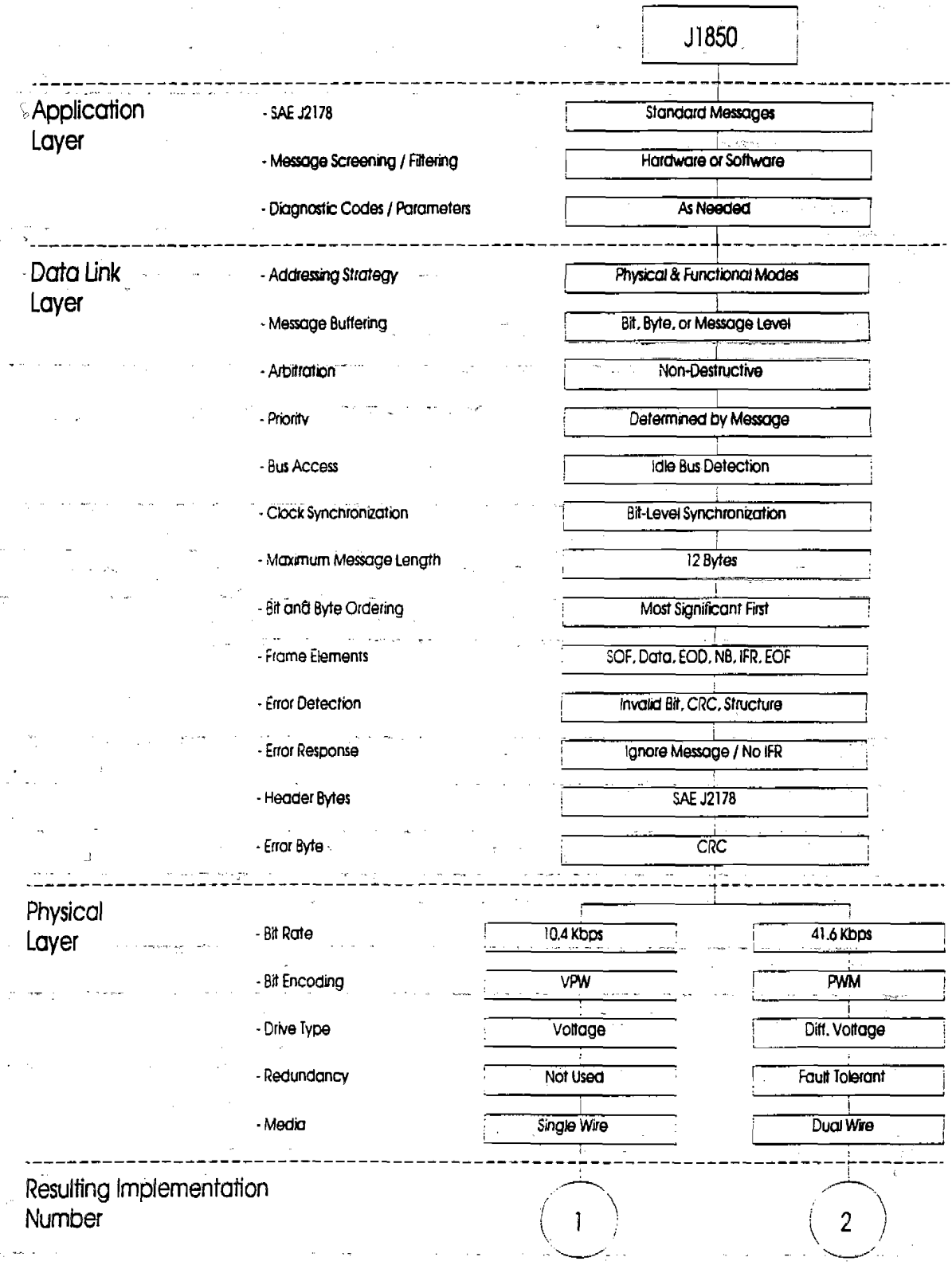


FIGURE 1–MAP OF SAE J1850 TO THE ISO OSI MODEL

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 1	IFR Required IFR Not Allowed
Y	Addressing Mode	0 1	Functional Addressing Physical Addressing
ZZ	Specific Message Type	0 0 0 1 1 0 1 1	The meaning for these values are dependent on K & Y above. These meanings can be found in J2178/1.

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

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.

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

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.

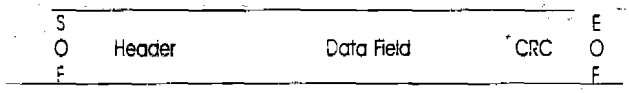
5.3.5 IDLE BUS (IDLE)—Idle bus is defined as any period of passive bus state occurring after IFS. During an idle bus, any node may transmit immediately. Contention may still occur when two or more nodes transmit nearly simultaneously; therefore, resynchronization to rising edges must continue to occur.

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.



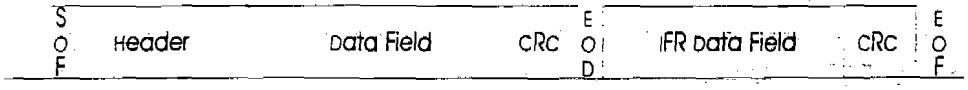
Type 0 - None



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

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:

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

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).

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

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

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.

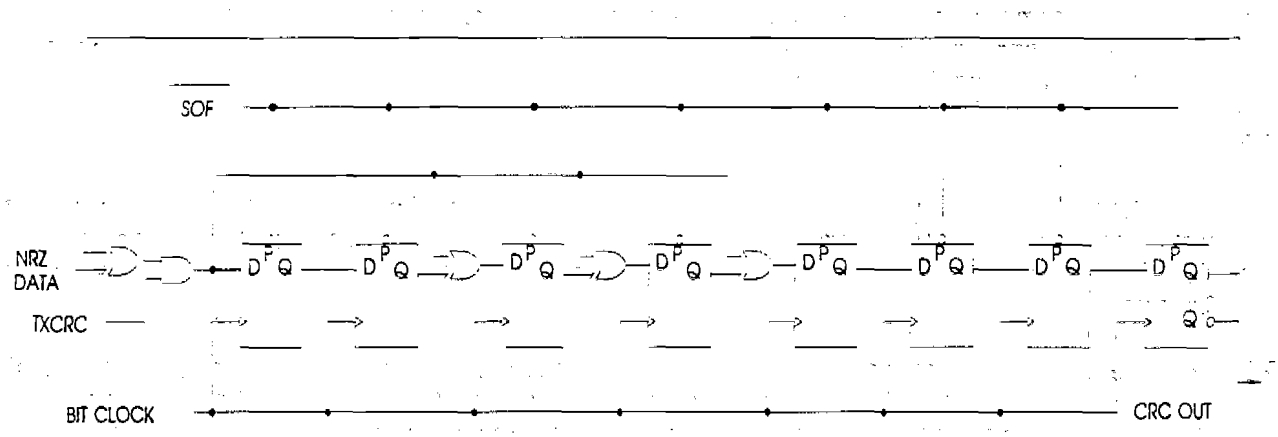


FIGURE 6–CRC GENERATOR

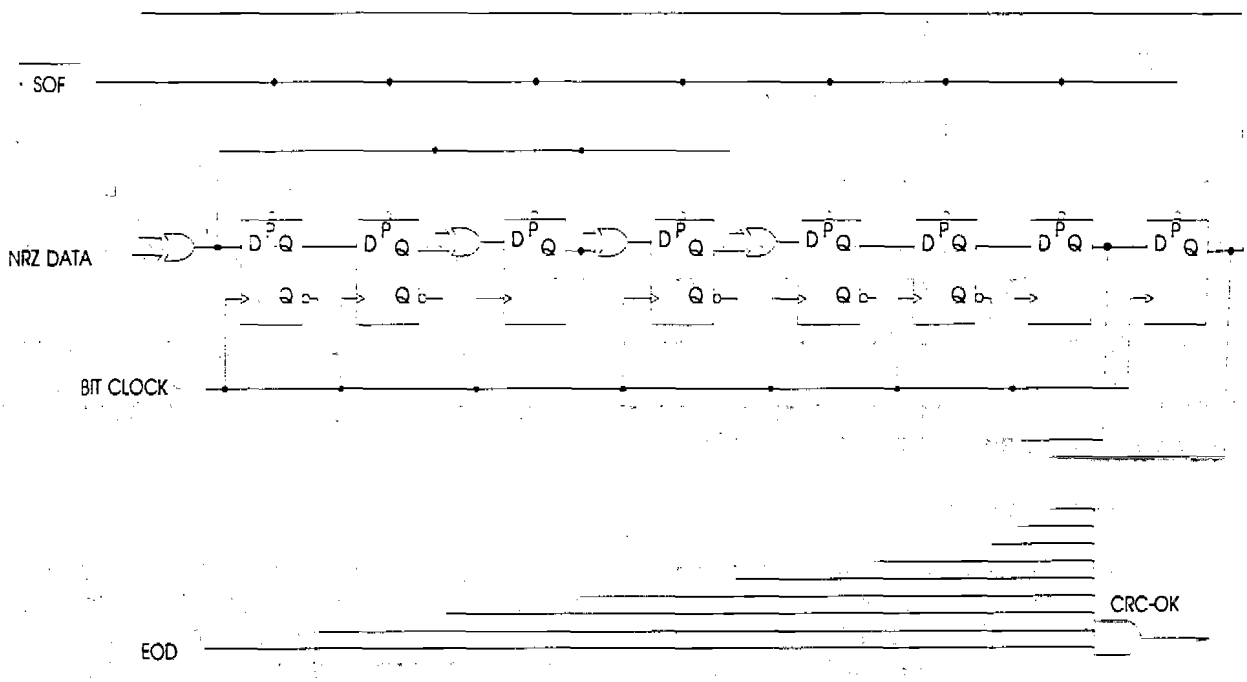


FIGURE 7–CRC CHECKER

5.4.4 CONCEPT OF VALID/INVALID BIT/SYMBOL DETECTION

5.4.4.1 Invalid Bit Detection—In some cases, data integrity may be increased by detecting the condition in the data stream where the received data bit does not match the specifications for either a "one" or a "zero" bit.

5.4.4.2 Invalid Frame Structure Detection—Regardless of data encoding, data integrity may be increased by detecting the condition when an EOD or EOF occurs on a non-byte boundary within the data stream, or the frame exceeds the maximum frame length.

5.5 Error Response

5.5.1 TRANSMIT—When an originator of a frame detects an error condition on the network (i.e., one of the error conditions defined in 5.4), the originator must discontinue the transmit operation prior to the start of the next bit. After the specified period of IFS or reception of an edge after EOF, the originator is allowed to retransmit the frame.

5.5.2 RECEIVE—If a frame is received and the frame contains an error (i.e., one of the error conditions defined in 5.4), the frame is to be ignored. If "In-Frame Response" is being used, the receiver must not respond to a received frame containing an error. This lack of response serves as a signal to the originator that an error was detected by the receiver.

6. Physical Layer Details—This section defines the requirements on the following physical layer attributes:

a. Media
b. Unit Load Specifications
c. Maximum Number of Nodes
d. Maximum Network Length
e. Media Characteristics
f. Data Bit/Symbol Definition/Detection
g. Network Wake-Up Via Physical Layer
h. Physical Layer Fault Considerations
i. EMC Requirements

Specific parametric values associated with the physical layer are contained in Section 7.

6.1 Physical Layer Media—Although this specification focuses on the data carrying media, it is assumed that each node shall be supplied with appropriate power and ground.

6.1.1 SINGLE WIRE—The network medium for the single wire voltage drive shall be a single random lay wire.

6.1.2 DUAL WIRES—The network medium for the dual wire voltage drive shall be either a parallel wire pair separated by a constant distance, or a twisted pair of wires.

6.1.3 ROUTING—No Restrictions

6.2 Unit Load Specifications—The electrical loading effect of each device connected to this network will be measured in terms of unit loads. A unit load is a nominal value which, if all nodes correspond to one unit load, will allow the maximum specified number of nodes to be connected to the network. There is no requirement that a given node must be equal to a standard unit load, but the combination of all load values must not exceed the limits for any given system.

6.3 Maximum Number of Nodes–The maximum number of nodes, assuming each node is the equivalent of a standard unit load, is specified in Section 7.

6.4 Maximum Network Length–The maximum medium length between any two nodes shall not exceed the value specified in Section 7.

6.4.1 ON-VEHICLE/OFF-VEHICLE–The maximum network length, maximum capacitance value and minimum load/termination resistance values for any off-vehicle equipment have been specified in 7.3. Because all applications must allow for such off-vehicle equipment, the allowed maximum on-vehicle loads shall be limited to account for this level of off-vehicle loading.

6.5 Media Characteristics– The characteristics of the media are as specified in Section 7.

6.6 Data Bit/Symbol Definition/Detection– The data bus can be in one of two valid states – active or passive. For clarity in the following sections, a rising edge is a transition from the passive to active state and a falling edge is a transition from the active to the passive state.

There are two methods of bit encoding specified in this document, Pulse Width Modulation (PWM) and Variable Pulse Width (VPW) modulation. The timing diagrams that follow represent the requirements for the logical waveform. It is the transmitter's responsibility to transmit bits/symbols which are valid (i.e., meets these specifications). In some contention situations, the transmitter will have to re-synchronize to ensure that the falling edge is within specification. The requirements associated with the reception of these bits and symbols are not stated explicitly in this specification, but are to be derived from transmitter specifications by the module or circuit designer. It is expected that the receiver will employ a simple clock-driven digital filter and digital integrator or majority vote sampling circuit for decoding data and maintaining "clock" synchronization. All timing requirements are specified in Section 7.

The following bits/symbols are defined for both PWM and VPW:

a. One "1" bit
b. Zero "0" bit
c. Start of Frame (SOF)
d. End of Data (EOD)
e. End of Frame (EOF)
f. Inter-Frame Separation (IFS)

The Normalization Bit (NB) is only applicable for VPW implementations and is therefore only defined for VPW.

6.6.1 PULSE WIDTH MODULATION (PWM)–The following values represent nominal timing, detailed timing requirements for each bit/symbol can be found in Section 7.

6.6.1.1 The One "1" and Zero "0" Bits (see Figures 8 and 9)

a. "1" Bit - A "1" bit is characterized by:

(1) A rising edge that follows the previous rising edge by at least Tp3. Two rising edges shall never be closer than Tp3.

(2) A falling edge that occurs Tp1 after the rising edge.

OMEGA EXHIBIT 2037

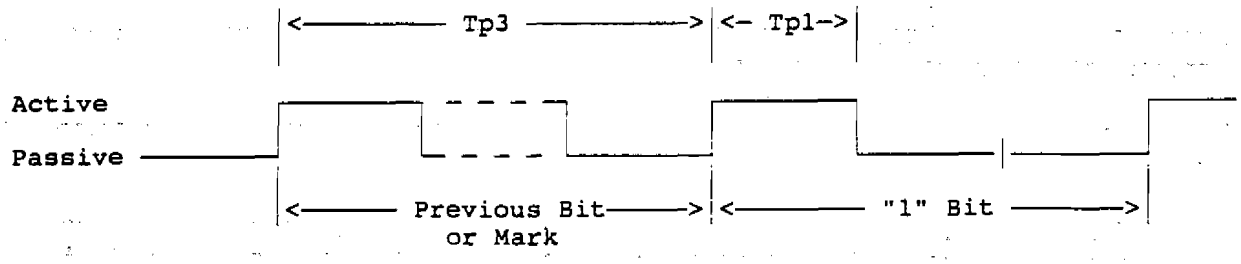


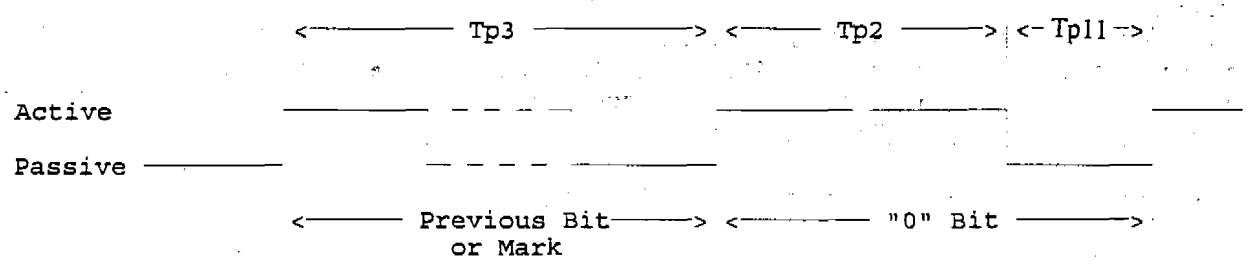
FIGURE 8—"1" BIT DEFINITION

b. "0" Bit - A "0" bit is characterized by:

(1) A rising edge that follows the previous rising edge by at least Tp3. Two rising edges shall never be closer than Tp3.

(2) A falling edge that occurs Tp2 after the rising edge.

(R) (3) A next data bit rising edge that occurs Tp11 after the previous falling edge (if applicable).



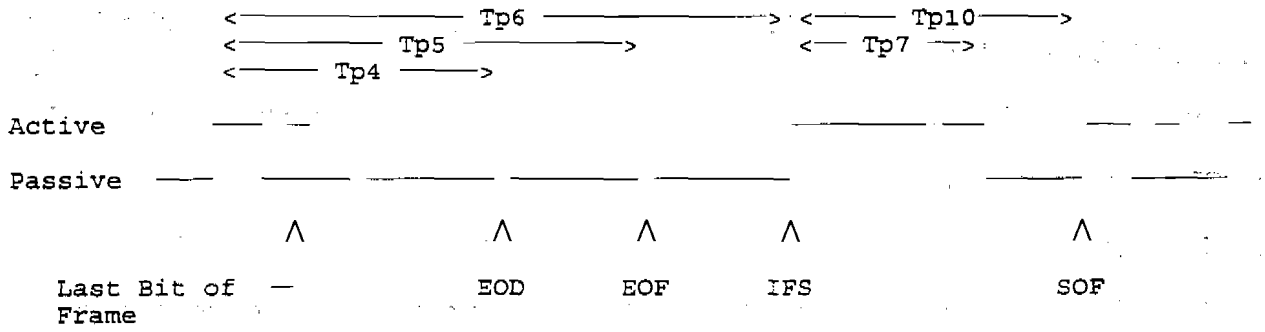
(R) FIGURE 9—"0" BIT DEFINITION

6.6.1.2 Start of Frame (SOF)—The Start of Frame (SOF) mark has the distinct purpose of uniquely determining the start of a frame (see Figure 10). The SOF is characterized by:

a. A reference rising edge that follows the previous rising edge by at least Tp5.

b. A falling edge that occurs Tp7 after the reference rising edge.

(R) c. The rising edge of the first data bit will occur at Tp10 after the reference rising edge.



(R) FIGURE 10–FRAME SYMBOLS

NOTE–Last bit of a frame may be the last data bit, last CRC bit, or last In-Frame Response bit.

6.6.1.3 End of Data (EOD)–End of Data 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 immediately after the EOD bit (see Figure 11). If the In-Frame Response feature is not used, then the bus would remain in the passive state for an additional bit time, thereby signifying an End of Frame (EOF).

For In-Frame Response, the response byte(s) are driven by the responders and begin with the rising edge of the first bit of the response, Tp4 after the rising edge of the last bit sent from the originator of the frame.

If the first bit of the response byte does not occur at Tp4, and the bus remains passive for one additional bit time (total time Tp5) then the originator and all receivers must consider the frame complete (i.e., EOD has been transformed into an EOF).

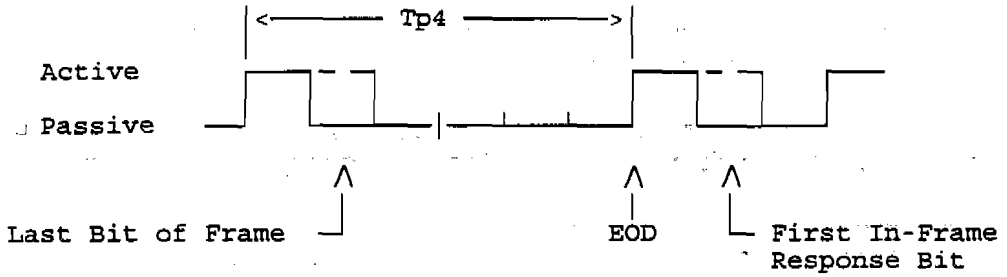


FIGURE 11–END OF DATA SYMBOL

NOTE–Last bit of a frame may be the last data bit, last CRC bit, or last In-Frame Response bit.

6.6.1.4 End of Frame (EOF)–The completion of the EOF defines the end of a frame (by definition, an EOD forms the first part of the EOF - see Figure 13). 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 (Tp5 after the rising edge of the last bit), all receivers will consider the transmission complete.

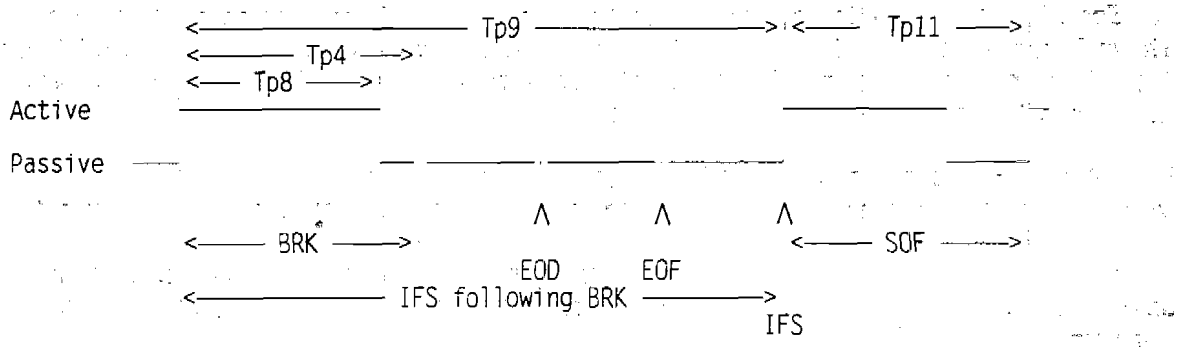
6.6.1.5 Inter-Frame Separation (IFS)–Inter-Frame Separation allows proper synchronization of various nodes during back-to-back frame operation.

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

a. IFS minimum has expired. (Tp6 after the rising edge of the last bit).

b. EOF minimum and another rising edge has been detected. (Tp5 after the rising edge of the last bit).

6.6.1.6 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 (see Figure 12). The PWM Break symbol is an extended SOF symbol and will be detected as an "invalid" symbol to some devices, which will then ignore the current frame, if any. Following the break symbol, an IFS following BRK period (Tp9 after the rising edge of the break) is needed to resynchronize the receivers. If the "Breaking" device wishes to obtain guaranteed access to the bus, the highest priority frame must then be sent, otherwise, other frames may gain access under the normal rules of arbitration.



(R) FIGURE 12–PWM BREAK SEQUENCE

6.6.1.7 Idle Bus (Idle)–Idle bus is defined as any period of passive bus state occurring after IFS minimum (see Figure 13). A node may begin transmission at any time during idle bus.

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.

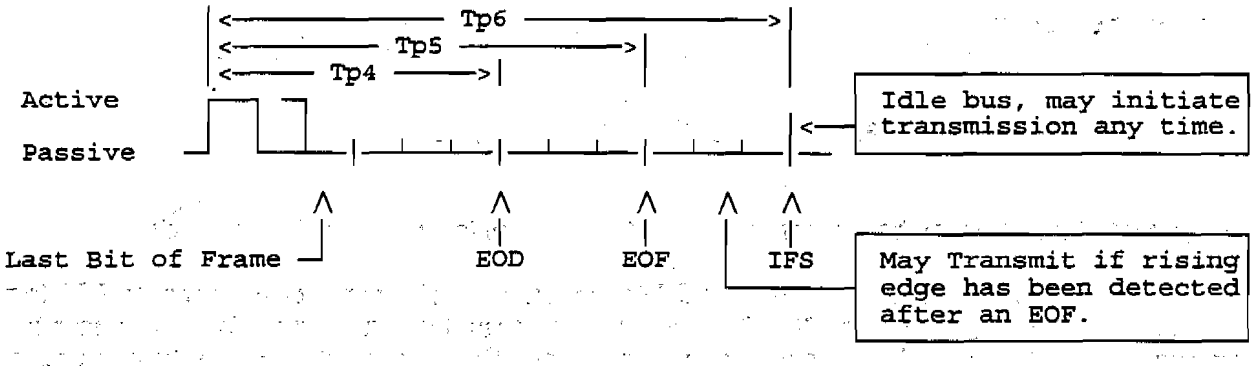


FIGURE 13–EOF AND IDLE BUS DEFINITION

NOTE–Last bit of a frame may be the last data bit, last CRC bit, or last In-Frame Response bit.

6.6.1.8 PWM Symbol Timing Requirements–The symbol timing reference for PWM encoding is based on transitions from the passive state to the active state. The SOF and each data bit in PWM has a "leading edge" from which all subsequent timing is derived. The transition from active to passive (which occurs within the SOF or data bits) is not used as a timing reference. The leading edge is used as the only reference because the transition from passive to active appears on the bus wires as a fast clean edge while the transition from active to passive is slow and ambiguous due to variations in network capacitance.

Paragraph 7.3.2.1 defines the timing values for PWM at 41.6 Kbps. Values are provided for the transmitter and receiver (based on the suggested bit decoder implementation).

6.6.2 VARIABLE PULSE WIDTH MODULATION–The SOF symbol, "0" bit, and "1" bit are defined by the time between two consecutive transitions and the level of the bus, active or passive. The EOD, EOF, IFS, and Break symbols are defined simply by the amount of time that has expired since the last transition. EOD, EOF, and IFS are all passive symbols and the Break is an active symbol. Therefore, there is one symbol per transition and one transition per symbol. The end of the previous symbol starts the current symbol. The following values represent nominal timing, detailed timing requirements for each bit/symbol can be found in Section 7.

6.6.2.1 The One "1" and Zero "0" Bits–A "1" bit is either a Tv2 passive pulse or a Tv1 active pulse. Conversely, a "0" bit is either a Tv1 passive pulse or a Tv2 active pulse (see Figure 14). The pulse widths change between passive and active bus states in order to accommodate the arbitration and priority requirements as specified in 6.7.

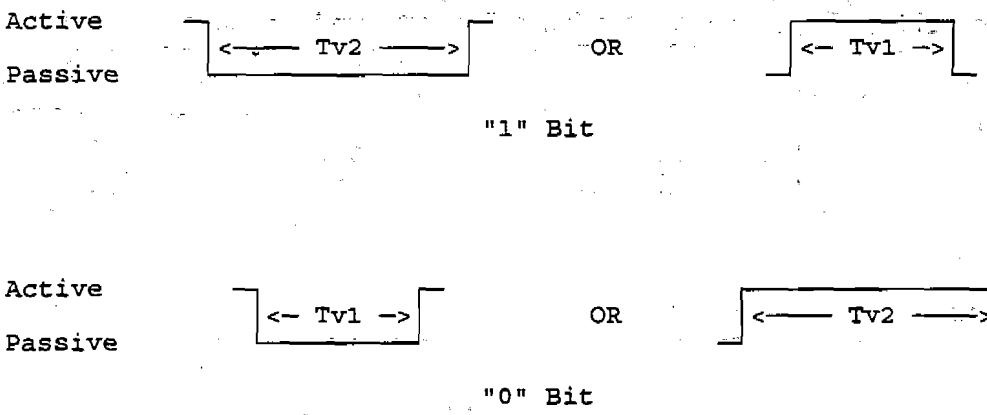


FIGURE 14–ONE AND ZERO BIT DEFINITIONS

6.6.2.2 Start Of Frame (SOF)–SOF is an active pulse, Tv3 in duration (see Figure 15).

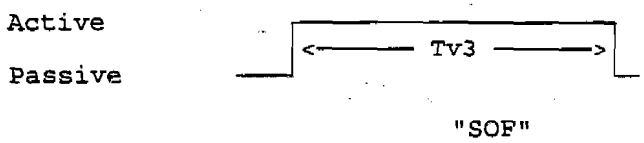


FIGURE 15–START OF FRAME (SOF) SYMBOL

6.6.2.3 End Of Data (EOD)–EOD is a passive pulse, Tv3 in duration (see Figure 16).

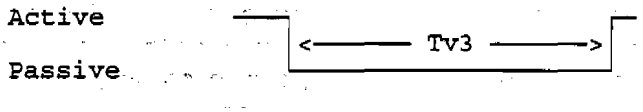


FIGURE 16–END OF DATA (EOD) SYMBOL

6.6.2.4 End of Frame (EOF)–EOF is a passive pulse, Tv4 in duration (see Figure 17).

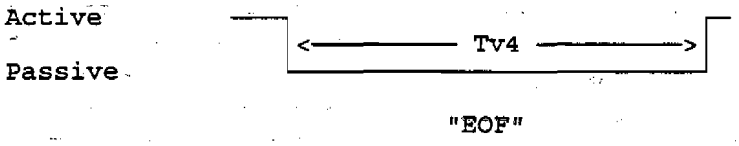


FIGURE 17–END OF FRAME (EOF) SYMBOL

6.6.2.5 In-Frame Response Byte(s)/Normalization Bit–The "In-Frame Response" (IFR) is transmitted by the responder and begins after the passive EOD symbol. For Variable Pulse Width Modulation, the first bit of the IFR data is also passive. Therefore, it is necessary to generate a normalization bit to follow the EOD symbol. The responding device generates the normalization bit prior to sending the IFR data. This normalization bit defines the start of the IFR and can take two forms. The first form is an active short period (Tv1) and the second form is an active long period (Tv2). Figure 18 illustrates the IFR using the normalization bit. The normalization bit can also be used to indicate what type of response is expected during the IFR portion of the frame. The preferred method is to use an active short bit (Tv1) to indicate that the IFR DOES NOT contain a CRC (i.e., IFR types 1 or 2). An active long bit (Tv2) would therefore indicate that the IFR DOES contain a CRC (i.e., IFR type 3). This is only a preferred method, and individual manufacturers are allowed to implement the normalization bit per their requirements. However, all future SAE J1850 applications are urged to implement the normalization bit using the preferred method described above.

If in-frame response bytes are used, the overall frame/message length limit remains in effect. The sum total of data bytes, CRC byte, and in-frame response bytes shall not exceed the value specified in Section 7.

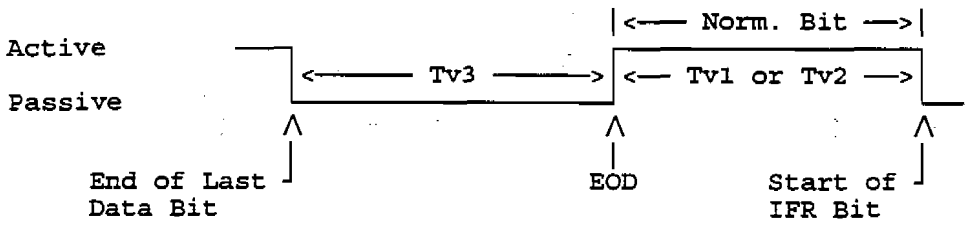


FIGURE 18–NORMALIZATION BIT

6.6.2.6 *Inter-Frame Separation (IFS)*–Inter-Frame Separation is used to allow proper synchronization of various nodes during back-to-back frame operation.

A transmitter that desires bus access must wait for either of two conditions before transmitting a SOF (see Figure 19):

a. IFS minimum has expired (Tv6).

b. EOF minimum and another rising edge has been detected (Tv4).

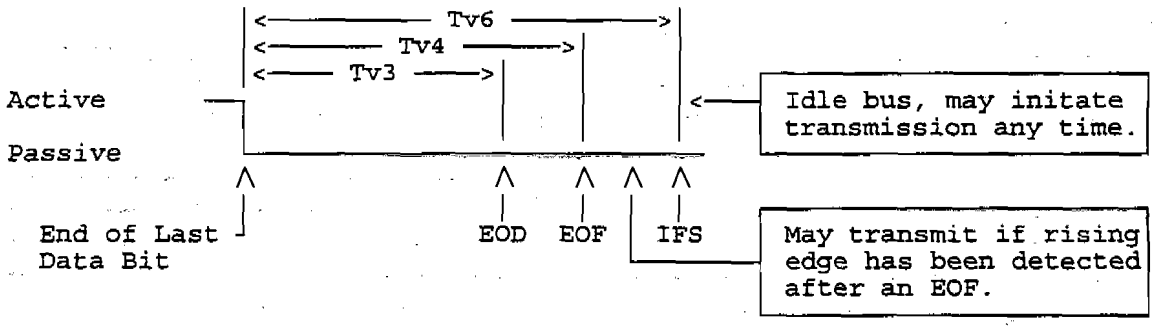


FIGURE 19–INTER-FRAME SEPARATION

6.6.2.7 *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 (see Figure 20). The VPW Break symbol will be detected as an "invalid" symbol to some devices, which will then ignore the current frame, if any. The VPW Break symbol is a long active period (≥ Tv5). Following the break symbol, an IFS period (Tv6) is needed to resynchronize the receivers and the normal IFS rules for transmitting a SOF during back-to-back operation apply. If the "Breaking" device wishes to obtain guaranteed access to the bus, the highest priority frame must then be sent, otherwise, other frames may gain access under the normal rules of arbitration.

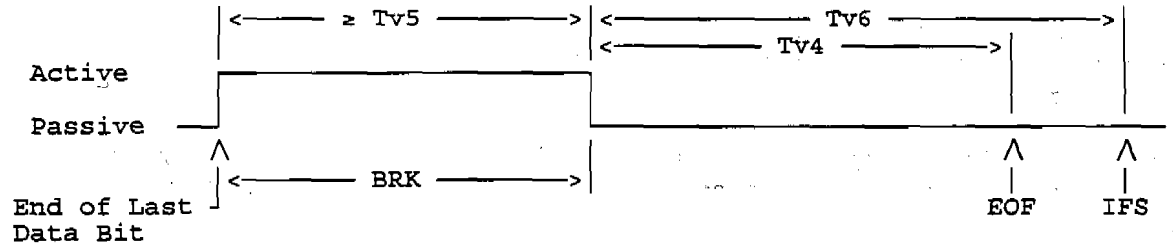


FIGURE 20–BREAK SIGNAL

6.6.2.8 *Idle Bus (Idle)*–Idle bus is defined as any period of passive bus state occurring after IFS. A node may begin transmission at any time during idle bus.

An idle bus will exist after IFS (Tv6). Contention may still occur when two or more nodes transmit nearly simultaneously; therefore, resynchronization to rising edges must continue to occur.

6.6.2.9 VPW Symbol Timing Requirements– The most important factor in symbol timing uncertainty is the edge position uncertainty due to the time taken to make a transition between $V_{ol,max}$ and $V_{oh,min}$ (in either direction). The maximum allowable transition time, $T_{t,max}$ (the area between $V_{ol,max}$ and $V_{oh,min}$), bounds the time span between the earliest and latest node to recognize a transition and is a key design parameter. As $T_{t,max}$ is reduced it becomes more and more difficult to design a driver which also meets the necessary EMI requirements. In this manner, the corners of the waveform, which are a major contributor to the radiated contents of the signal, do not fall within the limits imposed by $T_{t,max}$. as found in Section 7.

Other factors that affect the transmitted pulse width are oscillator tolerance and variations in delay through the receiver, noise filter, and driver. For a fixed oscillator and a well-designed digital filter, most of the variation is in the time it takes the driver to leave the current state and start the transition. The various factors (plus some guard band and allowance for alternative implementations) can be lumped into a single set of limits, $T_{x,min}$ and $T_{x,max}$, for each symbol. Each is measured from the trip point of the previous transition as seen by the transmitting node (assuming a step input) to the beginning or end of the transition at $V_{oh,min}$ or $V_{ol,max}$.

The pulse width as seen by another node, which may perceive the leading edge either sooner or later than the transmitting node, can range from $T_{x,min} - T_{t,max}$ to $T_{x,max} + T_{t,max}$ in absolute terms. This range represents a receiver's required acceptance range for a given symbol. The actual acceptance range must be wider to allow for receiver oscillator tolerance and any implementation-dependent uncertainties or constraints. The necessary guard band limits how close together symbols can be defined. To keep the symbols short, there is no space allocated for an unambiguous (with normal tolerances) forbidden zone between symbols.

The time windows are not affected by multiple nodes trying to transmit at the same time during arbitration. This is because a single node effectively dominates each transition. It is either the first node to leave the passive state or the last node to leave the active state. Although the fastest or slowest node dominates a particular transition, the contention scheme assures that the highest priority frame always wins regardless of which node started transmitting first.

The purpose of the noise filter is to eliminate impulse noise which may exceed the steady-state noise margin and to minimize the need for hysteresis at the receiver input. The delay through the filter is compensated for in the timing logic. A specific implementation of the filter is not required for compatibility so long as the delay is properly compensated and the uncertainty bounds are not exceeded. In the presence of arbitrary noise during the transition period, the filter should respond as though a single step input had occurred at some point within that period.

The symbol limits defined in Section 7 are consistent with $T_{t,max}$ and the specified oscillator tolerance. T_{nom} is the nominal symbol time with no oscillator error and the receiver detecting the transition at V_t (see analysis in Appendix D).

6.7 Contention/Arbitration/Priority– A contention situation arises when more than one node attempts to access the bus at essentially the same time.

6.7.1 CONTENTION DETECTION–Contention detection is the recognition of conflicting symbols or bits. The process of bit-by-bit arbitration allows conflicting frame transmissions to be detected. A node that detects a difference between the symbol or bit it receives and the symbol or bit it is currently transmitting has detected contention to the transmission of its frame. Only the one frame that wins all conflicts of different symbols and bits with all the other nodes that began transmitting during that frame will not detect contention.

OMEGA EXHIBIT 2037

6.7.2 BIT-BY-BIT ARBITRATION—The bit-by-bit arbitration scheme described as follows settles the conflicts that occur when multiple nodes attempt to transmit frames simultaneously. This scheme is applied to each symbol/bit of the frame, starting with the SOF symbol and continuing until the end of the frame. Bit-by-bit arbitration is based on the use, at the physical layer, of two values of the bus called the active state and the passive state. All symbols and bits are encoded on the bus by the physical layer as combinations of active and passive state signals. During simultaneous transmissions of active state and passive state signals on the bus, the resultant state on the bus is always active (active state dominates). If the transmitting node detects a signal state on the bus that is different from the state being transmitted by the node during the header portion of the frame, the node must discontinue the transmit operation prior to the start of the next bit. If the transmitting node detects a signal state on the bus that is different from the state being transmitted by the node during the data portion of the frame (following the header), the process used to cease transmission is implementation specific. Some possible options are:

a. Discontinue the transmit operation prior to the start of the next bit (similar to the action taken if contention is detected during the header phase). If transmission of a message is prematurely terminated on a byte boundary due to unexpected contention detection following the header, care must be taken by receiving nodes not to accept the message as a valid one. There is a 1 in 256 chance that the last byte received is the CRC of the previous bytes and would therefore appear to be a valid message. In this case, a node may need to validate the received message to ensure it is of the correct length.

b. Transmit additional bits (< 8) when contention is detected on a byte boundary. This ensures that a framing error will be received by all other receivers in the case of unexpected contention detection possibly due to noise.

Bus access is granted to nodes sending an active state signal over nodes sending a passive state signal. Figure 21 shows this operation on the physical layer, based on the two forms of modulation allowed (PWM and VPW).

The arbitration process begins with the SOF and continues through all the bits of the frames being sent. As each symbol or bit of all the simultaneous frames is transmitted, all of the nodes still transmitting after the last symbol or bit will detect whether any contention is taking place. Nodes that detect contention have, by definition, lost arbitration and will discontinue sending any further symbols or bits. Any remaining nodes will continue to send their symbols/bits until the next contention is detected. The node which obtains sole access to the medium is that which sends its symbols and bits without detecting any contention.

6.7.3 ARBITRATION AREA—The arbitration resolution described previously concerns all the symbols and bits between the SOF and the EOF including, in the case of an in-frame response, all the symbols and bits of the in-frame response. In other words, arbitration acts throughout the frame.

6.7.4 FRAME PRIORITY—The bit-by-bit arbitration mechanism allows the implementation of a frame priority system. When unique frames or, more particularly, when arbitration is resolved down to a single transmitter prior to any data values within the frame, a structure of relative frame priority is inherent.

Should two or more nodes attempt to access the bus within the same frame synchronization window (see IFS in 6.6.1.5 and 6.6.2.7), nondestructive arbitration will occur based on the bit value within each frame. The bus allows two states - active and passive. If an active state bit and a passive state bit are transmitted on the bus simultaneously, then the active state bit will override the passive state bit. Hence, frame arbitration occurs in a bit-wise manner. The result of the arbitration is that the node(s) sending lower priority frame(s) will recognize that they have lost arbitration and will discontinue transmitting before the next bit time. The node transmitting the highest priority frame will continue transmitting uninterrupted.

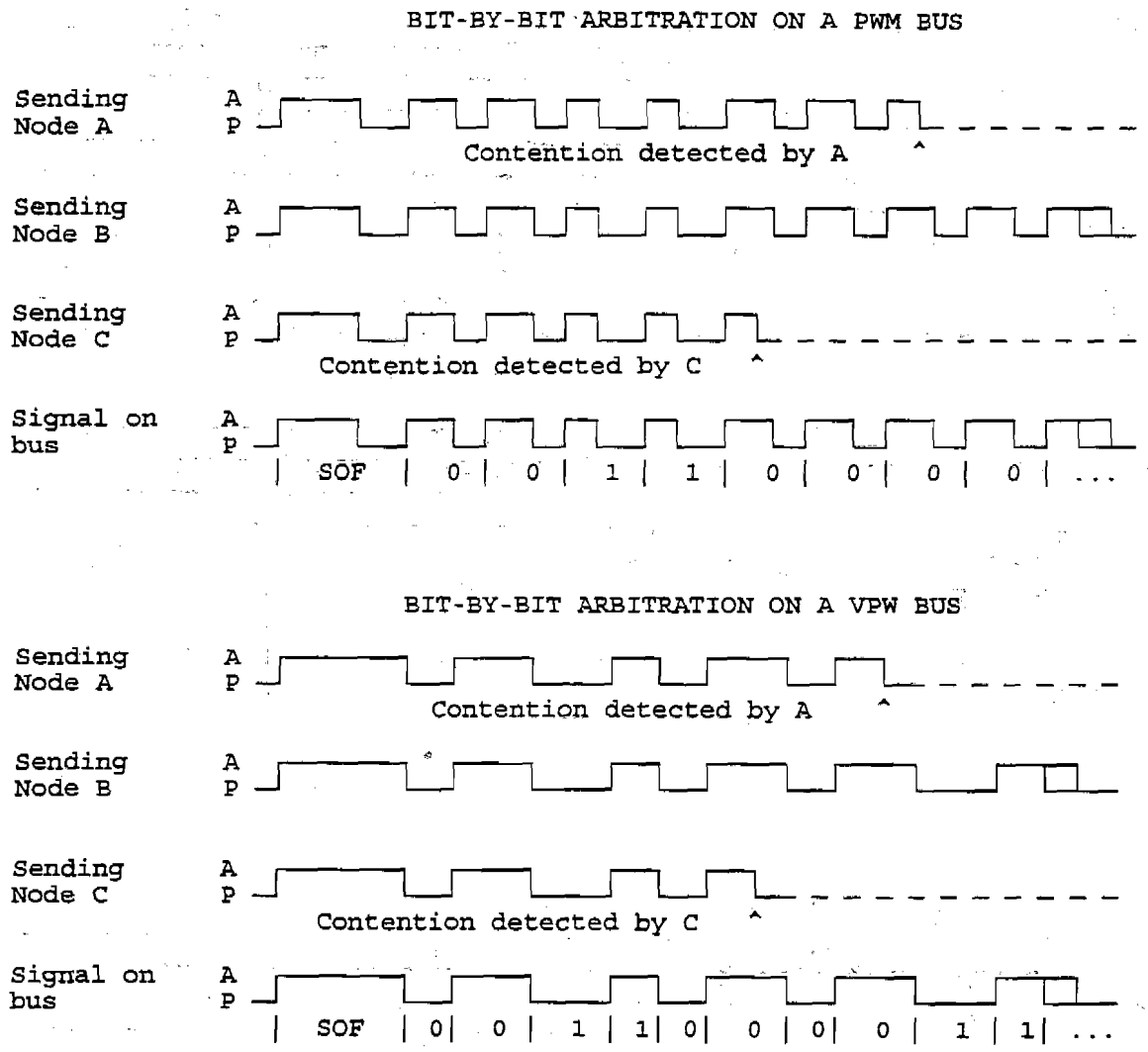


FIGURE 21–ARBITRATION

Based on the bit definitions contained in Section 6.6, the lowest value bytes immediately following the SOF will have the highest priority. Therefore, regardless of the number of bits allocated for "frame prioritization," the numerical value of zero will have the absolutely highest priority (that is, 000 is higher priority than 001 or 111).

6.8 Node Wake-Up Via Physical Layer–The transition to a functional/operating network from an unpowered or standby state is a common occurrence in vehicle multiplex systems. In the context of this document the Session Layer controls the transitions between the operating and the standby states.

Two perspectives are used to define the session layer:

a. The view of the media itself, without regard to the individual nodes on the network
b. The view from an individual node

Both are required for a complete definition of the possible states of network operation.

It is expected that a typical vehicle multiplex system may contain a mixture of unpowered and powered nodes, and that the individual nodes may themselves have both powered and standby states.

6.8.1 NETWORK MEDIA

6.8.1.1 Unbiased Network–An unbiased network is all conductors at ground voltage and the impedance of the conductors not controlled. No communication is possible on an unbiased network. The media must first be brought to the biased state before communication can take place. The transition of the network from the unbiased to the biased state may serve as a node wake-up signal for certain applications, but this is not a requirement (i.e., it is possible for individual nodes to be in the sleep state on a fully biased network or in the awake state on an unbiased network).

6.8.1.2 Biased Network–A biased network is all conductors at the "passive" voltage level (with no communication occurring) and with appropriate impedances capable of supporting communication. Individual nodes on the network may exist in any of the three states described as follows. Note that nodes which use the optional sleep state are required to wake up from the appropriate network signal within a defined wake-up period. In other words, all nodes which are capable of wake-up from network signals must do so; otherwise these nodes are considered "unpowered." This requirement assures a finite and limited delay to establish communication with nodes which may be in the sleep state.

The time required for the media to make the transition from the unbiased to the biased state is not defined in this document, since this parameter is largely application dependent and, in fact, may not even occur (e.g., media always biased). For the same reason, the time required for a node to make the transition between the unpowered state and the sleep or awake state is also not defined.

6.8.2 INDIVIDUAL NODES

6.8.2.1 Unpowered Node–An unpowered node is not capable of network communication, nor wake-up from network signal transitions.

6.8.2.2 Sleeping Node–A sleeping node may have an optional low-power standby mode capable of detecting network signal transitions for the purpose of wake-up. Any interface device in the sleep state can be awakened by any other interface device via network activity or awakened by its host via its interface to the host. There is no specified requirement for the transition from the awake state to the sleep state, since this is an implementation-specific issue.

6.8.2.3 Awake/Operational– An awake/operational node is fully capable of receiving and transmitting frames on the network. The maximum amount of time from the wake-up stimulus until the node is capable of communicating is implementation specific. A transition of the bus from the passive state to the active state shall be considered a "wake-up" signal to a sleeping node. Proper bus bias must be supplied by all nodes designated to supply bias when the network is powered.

6.9 Physical Layer Fault Considerations

6.9.1 REQUIRED FAULT TOLERANT MODES–The network must meet the requirements as defined per the following failure modes:

a. Node Power Loss–All nodes must continue to meet the network leakage current requirement during a loss of power (or low voltage) condition.

b. Bus Short to Ground–Network data communications may be interrupted but there shall be no damage to any node when the bus is shorted to ground.

c. Bus Short to Battery–Network data communications may be interrupted but there shall be no damage to any node when the bus is shorted to battery power.

d. Loss of Node Connection to Ground–When a node loses its ground connection, the remaining nodes shall remain capable of communications.

6.9.2 OPTIONAL FAULT TOLERANT MODES–The network may optionally meet the requirements as defined per the following failure modes:

a. Loss of Termination/Bias–Biasing and termination resistors shall be redundant such that no single point failure will cause the network to become inoperative.

b. Loss of Connection to Network–When a node becomes disconnected from the network the remaining nodes shall remain capable of communications.

c. Dual Wire Fault Tolerant Operation–Nodes on a dual wire bus may be capable of full communication (sending and receiving frames) at the specified bit rate in the presence of any one of the following faults occurring anywhere on the network:

(1) Bus "+" wire Open Circuit

(2) Bus "–" wire Open Circuit

(3) Bus "+" wire Shorted to Ground

(4) Bus "–" wire Shorted to Ground

(5) Bus "+" wire Shorted to Battery + (V_{batt})

(6) Bus "–" wire Shorted to Battery + (V_{batt})

(7) Bus "+" wire Shorted to any voltage between Ground and Battery

(8) Bus "–" wire Shorted to any voltage between Ground and Battery

Noise immunity and emissions may be somewhat degraded during the faulted period but shall return to normal after the fault is removed.

All nodes shall be protected from damage during the presence of these faults such that recovery to normal operation occurs automatically upon removal of the fault (i.e., faults shall not propagate through the network).

Continued communication is not required for the "Double Fault" condition of the Bus "+" wire shorted to the Bus "–" wire.

6.10 EMC Requirements– The vehicle manufacturer shall specify a minimum EMC level of operation for a module that utilizes this network interface device. A philosophical method for classification of functional performance can be found in SAE J1113 Part 1 Appendix B (formerly SAE J1113 Appendix B). A component manufacturer that designs the interface device to conform to the most severe classification of Class C Region I, for example, could be assured of adequate performance for all conditions.

The modules that communicate with each other via this interface device shall not generate levels of noise emissions (EMI) large enough to interfere with each other. For reference, the levels defined by CISPR/D/WG2 (Secretariat) 19 Sept 1989 may be used. In general, the specifications on wave shaping and transition rise and fall times control the EMI levels.

The vehicle manufacturers may find SAE J1211 helpful in specifying their multiplex systems. SAE J1879 may also be utilized for specifying components.

This document recommends the vehicle manufacturers use the following documents and the outlined EMC test plan defined in Appendix B. EMC and voltage "level" requirements specified by the Test Plan are given for reference only and the vehicle manufacturer specifications shall be used for compliance testing.

a. Radiated Emissions Antenna & Probe Test (CISPR/D/WG2(Secretariat) 19 Sept 1989)
b. Transfer Function, Current probe monitoring (SAE J1113 Part 2)
c. Transfer Function, Antenna monitoring (SAE J1113 Part 3)
d. RF Susceptibility (SAE J1113 Part 13)
e. Transient Susceptibility (SAE J1113 Part 10)

7. Parameters

7.1 Application Layer–The following Application Layer requirements shall exist whenever the network is used.

Bit Dominance - A "0" bit dominates over a "1" bit.

7.2 Data Link Layer

7.2.1 PULSE WIDTH MODULATION (PWM) AT 41.6 Kbps–The maximum frame length from SOF to EOF inclusive is 101 bit times. The maximum number of message bytes (i.e., excluding frame delimiters SOF, EOD, EOF, and IFS) is 12 bytes.

7.2.2 VARIABLE PULSE WIDTH (VPW) AT 10.4 Kbps–The maximum number of message bytes (i.e., excluding frame delimiters SOF, EOD, EOF, and IFS) is 12 bytes.

7.3 Physical Layer

7.3.1 GENERAL NETWORK REQUIREMENTS (see Table 2)

TABLE 2–GENERAL NETWORK PARAMETERS

Parameter Description	Parameter Value
On-Vehicle Network Length	35 meters
Off-Vehicle Network Length	5 meters
Total Vehicle Network Length	40 meters
Maximum number of standard unit loads (including off-vehicle equipment)	32 nodes
Off-vehicle load resistance	10.6 kohms min
Off-vehicle capacitance (each bus wire to signal or chassis ground, as measured at the SAE J1962 connector)	500 pF max

7.3.2 PULSE WIDTH MODULATION (PWM)

(R) *7.3.2.1 PWM Timing Requirements*– The following requirements, Table 3, are for a nominal bit time of 24 μs or 41.6 Kbps as seen on the network media.

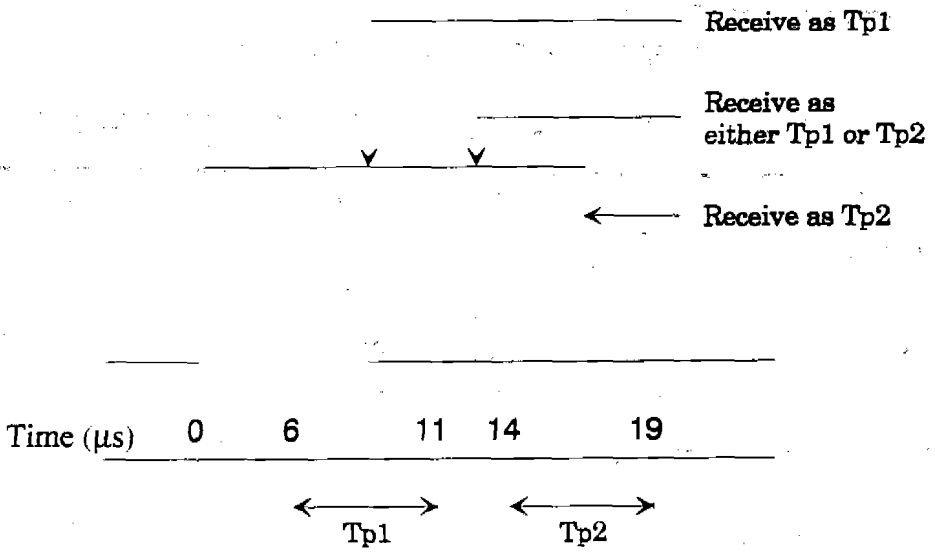
(R) TABLE 3–PWM PULSE WIDTH TIMES (μs)

Symbol	Tx,min	Tx,nom	Tx,max	Rx,min	Rx,max
Tp1: Active phase "1"	≥ 7	8	≤ 9	≥ 6	≤ 11
Tp2: Active phase "0"	≥ 15	16	≤ 17	≥ 14	≤ 19
Tp3: Bit time	≥ 23	24	≤ 25.5	≥ 22	≤ 27
Tp4: SOF/EOD time	≥ 47	48	≤ 51	≥ 46	≤ 63
Tp5: EOF time	≥ 70	72	76.5	≥ 70	N/A[1]
Tp6: IFS time	≥ 94	96	N/A[2]	N/A	N/A[2]
Tp7: Active SOF	≥ 30	32	≤ 33	≥ 30	≤ 35
Tp8: Active BRK	≥ 38	40	≤ 41	≥ 38	≤ 43
Tp9: BRK to IFS time	≥ 118	120	N/A[2]	N/A	N/A[2]
Tp10: SOF to Data rising edge	≥ 47	48	≤ 51	≥ 45	≤ 52
TP11 Passive to next rising edge	≥ 6	N/A	N/A	≥ 4	N/A

[1] EOF transitions into IFS and is not actually a "transmitted" symbol.
[2] Maximum IFS ends at next SOF.

Transmit tolerances include oscillator tolerances, physical layer delays (i.e., turn-on and turn-off delays), and other miscellaneous tolerances. Receive tolerances include considerations for voltage offsets between transmitter and receiver and other miscellaneous tolerances.

(R) Symbols received in the "gray" areas previously can be decoded as either the symbol before or after that of the "gray" area. For example, an active pulse of 12.5 μs can be decoded as either an active phase "1" (Tp1) or an active phase "0" (Tp2). An incorrect decision will be detected in the CRC error detection byte. Figure 22 gives an example of how a signal should be decoded based on the received pulse width.



(R) FIGURE 22–EXAMPLE OF RECEIVING A Tp1 OR Tp2 SYMBOL

Note that a pulse width detected between Tp1(min) and Tp1(max) must be decoded as an active phase "1" and a pulse width detected between Tp2(min) and Tp2(max) must be decoded as an active phase "0." However, a pulse width detected between Tp1(max) and Tp2(min) can be decoded as either an active phase "1" or active phase "0."

7.3.2.2 PWM DC Parameters (see Table 4)

TABLE 4—PWM DC PARAMETERS [1]

Parameter	Symbol	Min	Typ	Max	Units
Input High Voltage	V_{ih}	2.80	---	6.25	V
Input Low Voltage	V_{il}	-1.00	---	2.20	V
Output High Voltage	V_{oh}	3.80	---	5.25	V
Output Low Voltage	V_{ol}	0.00	---	1.20	V
Absolute Ground Offset Voltage	V_{go}	0.00	---	1.00	V
Bus (+) Driver & Bus (–) Termination Supply Voltage	V_{sup}	4.75	5.00	5.25	V
Receiver Input Common Mode Operating Range	V_{cm}	1.80	---	2.75	V
Receiver Hysteresis & Overdrive	V_{hys}	---	---	180	mV
Network Resistance (each wire)	R_{load}	85	---	378	ohms
Network Capacitance (each wire)	C_{load}	500	---	15,000	pF
Network Time Constant [2]	T_{load}	---	---	1.35	μs
Signal Transition Time	T_t	---	---	1.75	μs
Node Resistance (unit load, each wire)	R_{ul}	---	2,880	---	ohms
Node Capacitance (unit load, each wire to ground)	C_{ulg}	---	250	---	pF
Node Capacitance (unit load, wire-to-wire)	C_{ulw}	---	10	---	pF
Node Leakage Current (each wire - active state)	I_{leakA}	---	---	100	μA
Node Leakage Current (each wire - passive state, unpowered node)	I_{leakPU}	---	---	100	μA
Node Leakage Current (each wire - passive state, powered node)	I_{leakPP}	---	---	20	μA

1 Refer to Appendix D for an analysis of the PWM waveform.

2 The network time constant (T_{load}) is the product of R_{load} and C_{load}. Therefore, some combinations of network resistance and network capacitance are not allowed. The product of R_{load} and C_{load} must always be less than $T_{load,max}$.

7.3.3 VARIABLE PULSE WIDTH MODULATION (VPW)

7.3.3.1 VPW Timing Requirements– The following requirements, Table 5, show the VPW timing values.

TABLE 5–VPW PULSE WIDTH TIMES (μs)

Symbol	Tx,min	Tx,nom	Tx,max	Rx,min	Rx,max
Tv1: Short Pulse	≥ 49	64	≤ 79	> 34	≤ 96
Tv2: Long Pulse	≥ 112	128	≤ 145	> 96	≤ 163
Tv3: SOF/EOD time	≥ 182	200	≤ 218	> 163	≤ 239
Tv4: EOF time	≥ 261	280	N/A [1]	> 239	N/A [1]
Tv5: BRK time	≥ 280	300	≤ 5 ms	> 239	≤ 1.0 s
Tv6: IFS time	≥ 280	300	N/A [2]	> 280	N/A [2]

[1] EOF transitions into IFS and is not actually a "transmitted" symbol.
[2] Maximum IFS ends at next SOF.

7.3.3.2 VPW DC Parameters (see Table 6)

TABLE 6–VPW DC PARAMETERS[1]

Parameter	Symbol	Min	Typ	Max	Units
Input High Voltage [2]	V_{ih}	4.25	—	20.00	V
Input Low Voltage	V_{il}	—	—	3.50	V
Output High Voltage	V_{oh}	6.25	—	8.00	V
Output Low Voltage	V_{ol}	0.00	—	1.50	V
Absolute Ground Offset Voltage	V_{go}	0.00	—	2.00	V
Network Resistance	R_{load}	315	—	1,575	ohms
Network Capacitance	C_{load}	2,470	—	16,544	pF
Network Time Constant [3]	T_{load}	—	—	5.2	μs
Signal Transition Time	T_t	—		18.0	μs
Node Resistance (unit load)	R_{ul}	—	10,600	—	ohms
Node Capacitance (unit load)	C_{ul}	—	470	—	pF
Node Leakage Current	I_{leak}	—	—	10	μA

[1] Refer to Appendix C for an analysis of the VPW waveform.
[2] Individual manufacturers may require a higher upper limit ($V_{ih,max}$).
[3] The network time constant (T_{load}) is the product of R_{load} and C_{load}. Therefore, some combinations of network resistance and network capacitance are not allowed. The product of R_{load} and C_{load} must always be less than $T_{load,max}$.

8. Notes

8.1 Marginal Indicia–The (R) is for the convenience of the user in locating areas where technical revisions have been made to the previous issue of the report. If the symbol is next to the report title, it indicates a complete revision of the report.

PREPARED BY THE SAE VEHICLE NETWORK FOR MULTIPLEXING AND DATA COMMUNICATIONS STANDARDS COMMITTEE

APPENDIX A
CHECKLIST OF APPLICATION-SPECIFIC FEATURES

A.1 Figure A1 is a checklist provided as an aid to highlight the communication features of J1850.

FEATURES	Tx	Rx	Comments
FRAME ELEMENTS			
General Frame Elements : IFS, SOF, Data, CRC, EOF.			
End of Data (EOD)			
Normalization Bit (NB) - Tv1/Tv2			
BUS ACCESS			
Idle Bus			
Break (BRK)			
IN-FRAME RESPONSE			
Type 0 (None)			
Type 1 (Single Byte, Single Responder)			
Type 2 (Single Byte, Multiple Responder)			
Type 3 (Multiple Byte, Single Responder)			
ERROR DETECTION			
Cyclic Redundancy Check (CRC)			
Out of Range			
Invalid Bit			
Invalid Symbol			
Invalid Structure			
Invalid Message Length			
Number of Arbitration Bytes			
FAULT TOLERANCE			
Node Power Loss			
Bus Short to Ground			
Bus Short to Battery			
Loss of Node Ground Connection			

FIGURE A1–CHECKLIST OF APPLICATION-SPECIFIC FEATURES

FEATURES	Tx	Rx	Comments
Loss of Termination Resistance			
Loss of Network Connection			
Dual Wire Fault Tolerance			
HEADER BYTES			
Single Byte			
One Byte Consolidated			
Three Byte Consolidated			
RATE/SYMBOL ENCODING			
10.4 Kbps Variable Pulse Width Modulation (VPWM)			
41.6 Kbps Pulse Width Modulation (PWM)			
FEATURE ELEMENTS			
Maximum Frame Size			
Wake-Up Capability			

FIGURE A1 (CONTINUED)

OMEGA EXHIBIT 2037

APPENDIX B
I/O EMC TEST PLAN

B.1 Radio Disturbance From Vehicle Components– (CISPR/D/WG2(Secretariat) 19 Sept 1989) - See Figure B1 for diagram.

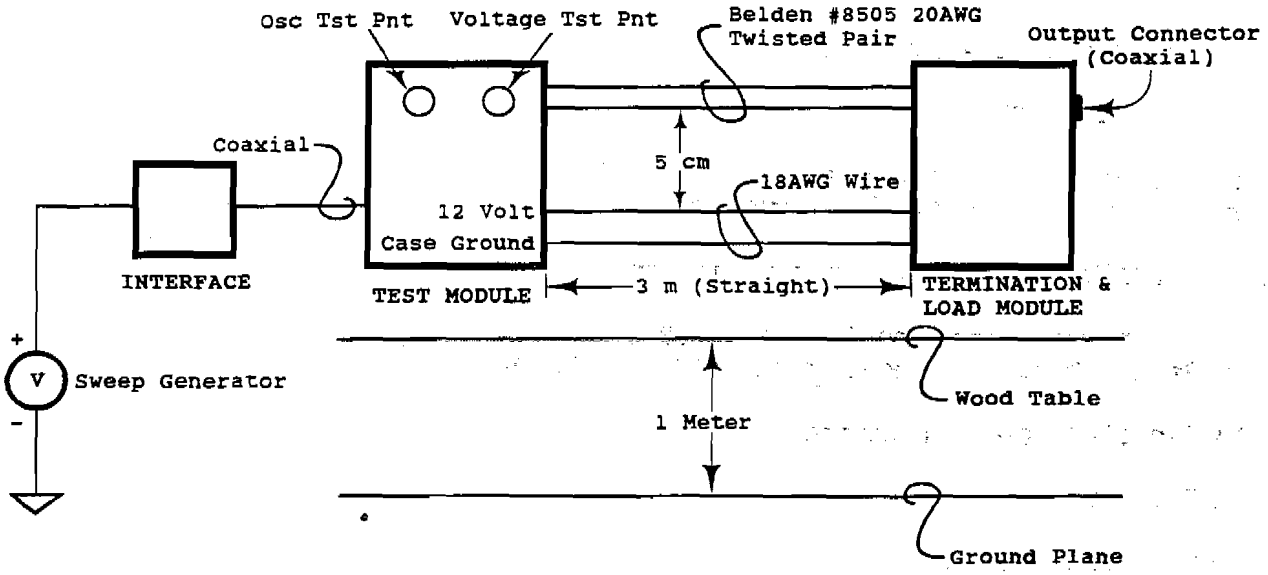


FIGURE B1–EMC TEST SETUP

B.1.1 Radiated Emissions Antenna Test

B.1.1.1 FREQUENCY RANGE–10 kHz to 1.0 GHz

B.1.1.2 BANDWIDTH SETTING

a. Frequency - 10 kHz to 149 kHz, Bandwidth - 1 kHz
b. Frequency - 150 kHz to 1 GHz, Bandwidth - 3 kHz

B.1.1.3 TEST DATA

B.1.1.3.1 Ambient Reference

a. 10 kHz modulation off
b. Both transmitter and receiver power off
c. Sweep signal off

B.1.1.3.2 Idle Bus State

a. 10 kHz modulation off
b. Both transmitter and receiver power on
c. Sweep signal off

B.1.1.3.3 Active Bus State

a. 10 kHz modulation on
b. Both transmitter and receiver power on
c. Sweep signal off

B.1.2 Radiated Emissions Probe Test

B.1.2.1 FREQUENCY RANGE–10 kHz to 200 MHz

B.1.2.2 BANDWIDTH SETTING

a. Frequency - 10 kHz to 149 kHz, Bandwidth - 1 kHz
b. Frequency - 150 kHz to 1 GHz, Bandwidth - 3 kHz

B.1.2.3 PROBE TYPE–As required to make measurements

a. Recommended probe type - Tektronix A6302 (0 - 29 MHz)
b. Recommended probe type - Ailtech 94111-1 (30 - 200 MHz)

B.1.2.4 PROBE DISTANCE–5 cm from part

B.1.2.5 TEST DATA

B.1.2.5.1 Ambient Reference

a. 10 KHz modulation off
b. Both transmitter and receiver power off
c. Sweep signal off

B.1.2.5.2 Idle State

a. 10 kHz modulation off
b. Both transmitter and receiver power on
c. Sweep signal off

B.1.2.5.3 Active Bus

a. 10 kHz modulation on
b. Both transmitter and receiver power on
c. Sweep signal off

B.2 Transfer Function–Electromagnetic Susceptibility Measurement Procedures for Vehicle Components

B.2.1 Current Probe Monitoring– Adapted from SAE J1113 Part 2 (Formerly SAE J1113 (Aug 87) Section 2).

a. Frequency - 30 Hz to 250 kHz
b. Amplitude - 1 V peak-to-peak at test point

B.2.2 Antenna Monitoring– Adapted from SAE J1113 Part 3 (Formerly SAE J1113 (Aug 87) Section 3).

a. Frequency: 250 kHz to 200 MHz
b. Attenuator input power: ≈ 25 mW to generate 1 V peak-to-peak at test point

B.2.3 Test Data

B.2.3.1 TRANSFER FUNCTION FROM VCC TO BUS

a. 10 kHz modulation on
b. Both transmitter and receiver power on
c. Sweep signal on

B.2.3.2 TRANSFER FUNCTION FROM GROUND TO BUS

a. 10 kHz modulation on
b. Both transmitter and receiver power on
c. Sweep signal on

B.3 RF Susceptibility– Electromagnetic Susceptibility Measurement Procedures for Common Mode Injection for compliance, test per SAE J1113 Part 13 (formerly SAE J1547).

B.3.1 Frequency Range– 1 MHz to 200 MHz.

B.3.2 Max Level– 100 mA RMS.

B.3.3 Procedure– Injection and monitoring to be applied to Bus pair only.

B.3.4 Test Data– Record the nature of any interaction occurring below the test level along with the current and frequency.

B.4 Transient Susceptibility– Test per SAE J1113 Part 10 (Adapted from ISO 7637/3).

Test Pulse Amplitude

a. Test Pulse 1: –30 V (Reference)
b. Test Pulse 2: +30 V (Reference)
c. Test Pulse 3a: –60 V (Reference)
d. Test Pulse 3b: +40 Vs (Reference)

APPENDIX C
VPW WAVEFORM ANALYSIS

C.1 VPW Waveform Analysis–Figure C1 shows a drawing of a bus waveform with various voltage levels and trip points. The voltage levels and trip points are defined as follows:

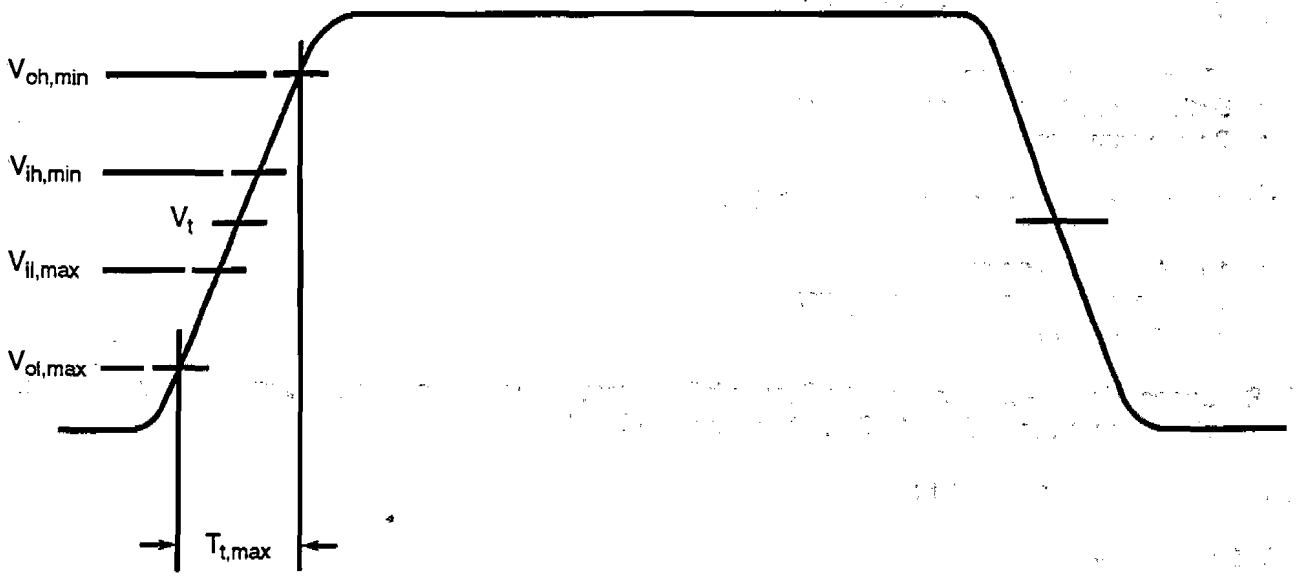


FIGURE C1–VOLTAGE LEVELS AND TRIP POINTS

C.2 Voltage Levels and Trip Points

C.2.1 $V_{oh,min}$–Minimum guaranteed output high voltage. This is also the highest trip point, with the source having no ground offset noise, and the receiver having 2 V of noise.

C.2.2 $V_{ol,max}$–Maximum guaranteed output low voltage. This is also the highest trip point, with the receiver having no ground offset noise, and the source having 2 V of noise.

C.2.3 V_t–Ideal receiver trip point.

C.2.4 $V_{ih,min}$–Minimum guaranteed input high voltage and is also the highest trip point with no offset noise.

C.2.5 $V_{il,max}$–Maximum guaranteed input low voltage and is also the lowest trip point with no offset noise.

C.3 VPW Pulse Width Analysis–Factors that affect the transmitted pulse width are oscillator tolerance and variations in delay through the source driver, and the medium. These factors, along with some guard banding, are lumped into a single set of limits called $T_{x,min}$ and $T_{x,max}$ for each bus symbol.

Equations C1 and C2 are used to generate the transmitted pulse values shown in Table C1:

$$T_{x,min} = (T_{nom} - T_{t,max}/2) * 0.98 - T_{x,mar} \quad \text{(Eq. C1)}$$

$$T_{x,max} = (T_{nom} + T_{t,max}/2) * 1.02 + T_{x,mar} \quad \text{(Eq. C2)}$$

TABLE C1–VPW PULSE WIDTH TIMES (μs)

Symbol	Tx,min	Tx,nom	Tx,max	Rx,min	Rx,max
Tv1: Short Pulse	49	64	79	34	96
Tv2: Long Pulse	112	128	145	95	162
Tv3: SOF/EOD time	182	200	218	164	237
Tv4: EOF time	261	280	N/A	241	N/A

(R) The ($T_{nom} \pm T_{t,max}$ /2) * 2% factor covers the 2% oscillator tolerance. The $T_{x,nom}$ and $T_{t,max}$ factors are given in Section 7. The $T_{x,mar}$ factor is assumed to be 5.0 which covers the rest of the factors (lumped variation in delay through the source driver and medium).

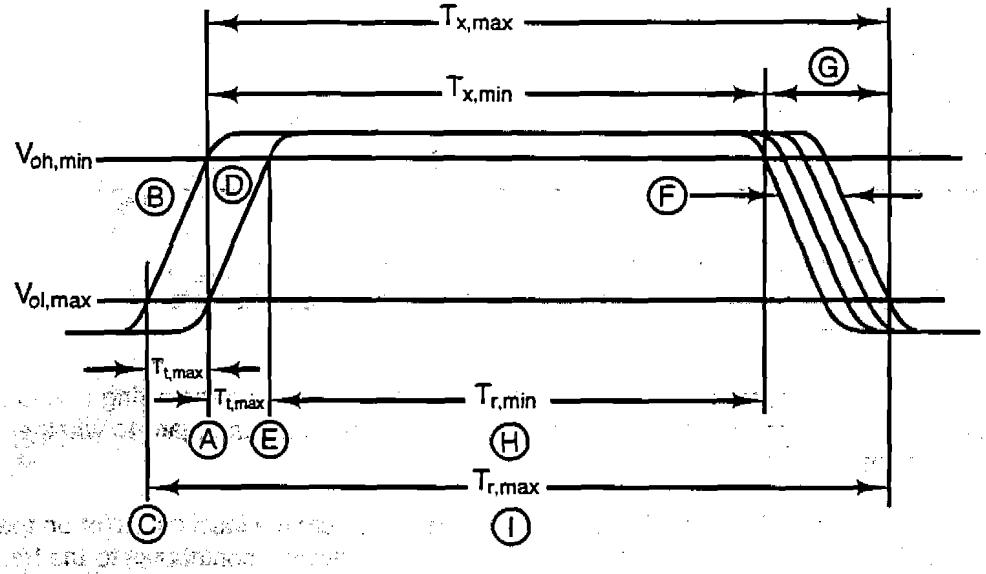
For VPW, mode synchronization is an integral part of symbol timing. All transmitting nodes reference their transmit timing from their receiver's perception of the previous edge without regard to whether that edge was due to their own or another transmitter.

Figure C2 shows a plot of T_x, $T_{x,min}$ and $T_{x,max}$. Each is measured from the ideal trip point on the leading edge of the waveform. The fact that what is seen at the source's own receiver contributes to the transmitted pulse width and implies that the source device could be using echoed back information to shape what is transmitted.

The pulse width seen by another node (receiver) can range from $T_{x,min} - T_{t,max}$ to $T_{x,max} + T_{t,max}$. This range comes from the variations in the transmitted pulse width combined with possible noise offset effects on the transmitted and receiving node. The $T_{x,min} - T_{t,max}$ situation occurs when a $T_{x,min}$ pulse width is transmitted by a source node with no ground offset noise, and received by a receiving node with a 2V of ground offset noise. This sets up the possibility of the receiver tripping at $V_{oh,min}$ on the leading and trailing edge of the waveform. Therefore the pulse width seen by another node for the this $T_{x,min} - T_{t,max}$ situation including the oscillator tolerance and guard banding is given by Equation C4. Equation C5 is derived by substituting Equation C1 for $T_{x,min}$ in Equation C4. The $T_{t,max}$ /2 factor is equal to zero since an ideal trip point and no ground offset was assumed. The $T_{x,max} + T_{t,max}$ situation occurs with a $T_{x,max}$ pulse being transmitted, the source node having 2V of noise, and the receiver having no offset. This sets up the possibility of the receiving node tripping at $V_{ol,max}$. Again the actual acceptance range must be wider to allow for the receiving node's oscillator tolerance and any implementation-dependent uncertainties or constraints. Similarly Equations C7 and C8 are derived.

The receiving node may perceive the leading edge sooner or later than the transmitting node (source node). This range represents a receiver's required acceptance range for a given bus symbol. Figure C2 shows a drawing of this acceptance range.

OMEGA EXHIBIT 2027



A - The trigger point on waveform "B" or "D" where the transmitting node sees the transition ending the previous symbol, and starts timing the current symbol. Take note that a node could trigger at any level of a transition between $V_{ol,max}$ and $V_{oh,min}$. The maximum and minimum trigger points of any given transition are illustrated by showing line A cutting through two different waveform transitions. This method of illustration allows separating the uncertainties of nodes sensing the beginning and ending of a symbol.

B - The earliest waveform that could trigger the transmitter at point A.

C - The earliest point on waveform "B" that could trigger any other node.

D - The latest waveform that could trigger the transmitter at point A.

E - The latest point on waveform "D" that could trigger any other node.

F - The waveform dispersion due to transmitter tolerances in oscillator, driver, etc.

G - The total transmitter spread when transition time limits are combined with the other tolerances in "F".

H - The shortest legitimate symbol time which can legitimately be seen under worst case conditions.

I - The longest legitimate symbol time which can legitimately be seen under worst case conditions.

NOTES–$T_{x,max}$ - Starts at $V_{oh,min}$ on wave "B"; $T_{x,min}$ - Starts at $V_{ol,max}$ on wave "D"

FIGURE C2–WAVEFORM TIMING PARAMETERS

The calculations for the received $T_{r,min}$ and $T_{r,max}$ are derived using the factors specified in section 7 for a 2 V ground offset range and a transition rise time of $T_{t,max}$. The transmitting node $T_{t,max}$ factor would be zero (0) if it was a perfect receiver and sensed a transition at the ideal trip point. However, for a real receiver the trip point $T_{tp,max}$ can be approximated by Equation C3 assuming a linear waveform rise time.

$$T_{tp,max} = T_{t,max} * ((V_{ih,min} - V_{il,max})/(V_{oh,min} - V_{ih,min})) \quad \text{(Eq. C3)}$$

The values for this range shown in Table C1 were arrived at using Equations C6 and C9. Note these values compare favorably with the values specified in Section 7, Table 5.

$$T_{r,min} = (T_{x,min} - T_{t,max}) * 0.98 - T_{r,mar} \quad \text{(Eq. C4)}$$

$$T_{r,min} = ([(T_{nom} - T_{t,max}/2) * 0.98 - T_{x,mar}] - T_{t,max}) * 0.98 - T_{r,mar} \quad \text{(Eq. C5)}$$

$$T_{r,min} = ([(T_{nom} - T_{tp,max}/2) * 0.98 - T_{x,mar}] - T_{t,max}) * 0.98 - T_{r,mar} \quad \text{(Eq. C6)}$$

$$T_{r,max} = (T_{x,max} + T_{t,max}) * 1.02 + T_{r,mar} \quad \text{(Eq. C7)}$$

$$T_{r,max} = ([(T_{nom} + T_{t,max}/2) * 1.02 + T_{x,mar}] + T_{t,max}) * 1.02 + T_{r,mar} \quad \text{(Eq. C8)}$$

$$T_{r,max} = ([(T_{nom} + T_{tp,max}/2) * 1.02 + T_{x,mar}] + T_{t,max}) * 0.98 + T_{r,mar} \quad \text{(Eq. C9)}$$

The 2% guard bands cover the oscillator tolerances of both transmitter and receiver and $T_{r,mar} = 4.0$ covers the other uncertainties, including receiver delay and digital filter delay. VPW bus symbols allow no forbidden zones between symbols.

Table C1 shows the VPW Pulse Width Timing Requirements

Filter Compensation–The reason for choosing a synchronous data encoding technique is to synchronize at every valid state transition. If the delays through the filter, receiver, and output drivers can be characterized into a constant value, this delay can be compensated for by the timing logic. If variations in delay caused by this Filter and I/O Hardware cannot be easily compensated for, then the Source Interface device variations should be included in the $\pm$ 5.0 μs factor defined in $T_{x,min}$ and $T_{x,max}$. All further, variations in delay and including a safety factor for dead zones between symbols for the Receiving device should be included in the $\pm$ 4.0 μs factor defined in $T_{r,min}$ and $T_{r,max}$.

APPENDIX D
PWM WAVEFORM ANALYSIS

D.1 PWM Waveform Analysis–Figure D1 shows a drawing of a typical bus waveform with various voltage levels and trip points. Table D1 contains the DC parameter specifications.

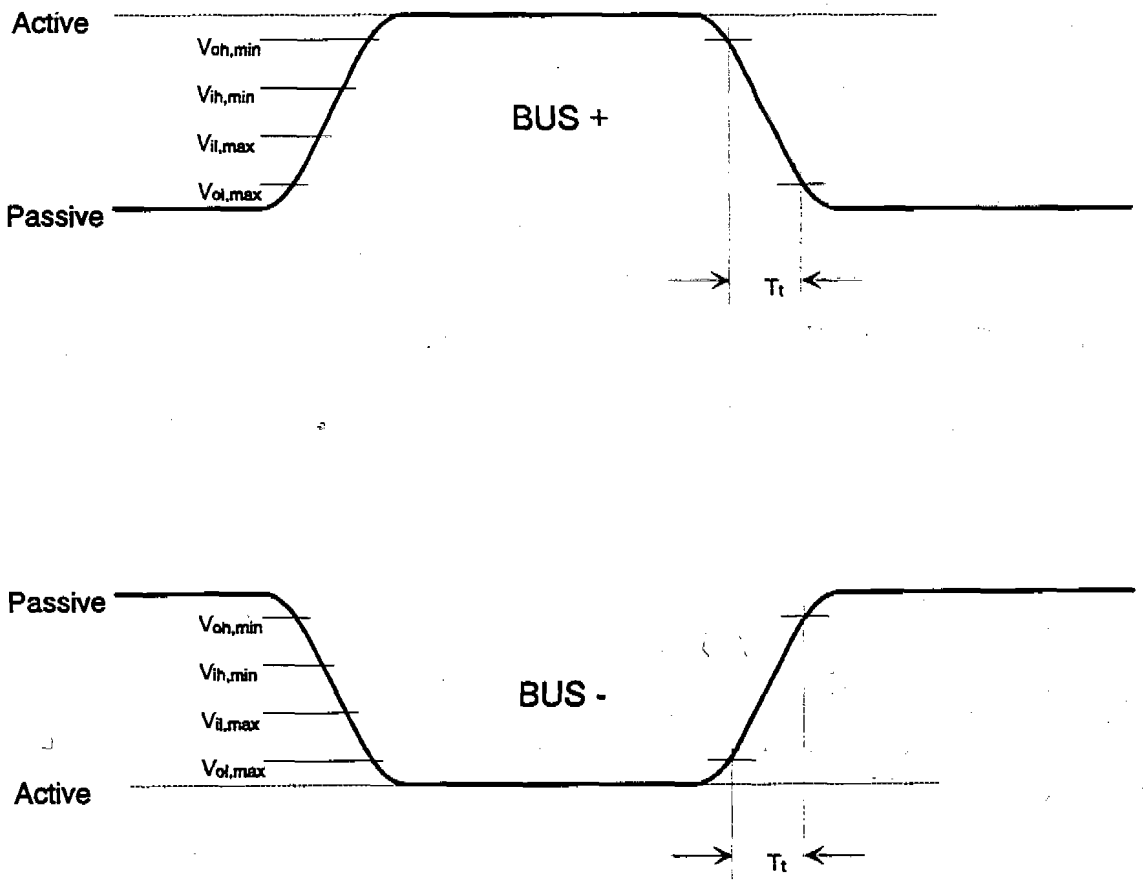


FIGURE D1–TYPICAL PWM WAVEFORM

TABLE D1—PWM DC PARAMETERS

Parameter	Symbol	Min	Typ	Max	Units
Input High Voltage	V_{ih}	2.80	—	6.25	V
Input Low Voltage	V_{il}	-1.00	—	2.20	V
Output High Voltage	V_{oh}	3.80	—	5.25	V
Output Low Voltage	V_{ol}	0.00	—	1.20	V
Absolute Ground Offset Voltage	V_{go}	0.00	—	1.00	V
Bus (+) Driver & Bus (–) Termination Supply Voltage	V_{sup}	4.75	5.00	5.25	V
Receiver Input Common Mode Operating Range	V_{cm}	1.80	—	2.75	V
Receiver Hysteresis & Overdrive	V_{hys}	—	—	180	mV
Network Resistance (each wire)	R_{load}	85	—	378	ohms
Network Capacitance (each wire)	C_{load}	500	—	15,000	pF
Network Time Constant [1]	T_{load}	—	—	1.35	μs
Signal Transition Time	T_t	—	—	1.75	μs
Node Resistance (unit load, each wire)	R_{ul}	—	2,880	—	ohms
Node Capacitance (unit load, each wire to ground)	C_{ulg}	—	250	—	pF
Node Capacitance (unit load, wire-to-wire)	C_{ulw}	—	10	—	pF
Node Leakage Current (each wire - active state)	I_{leakA}	—	—	100	μA
Node Leakage Current (each wire - passive state, unpowered node)	I_{leakPU}	—	—	100	μA
Node Leakage Current (each wire - passive state, powered node)	I_{leakPP}	—	—	20	μA

[1] The network time constant (T_{load}) is the product of R_{load} and C_{load}. Therefore, some combinations of network resistance and network capacitance are not allowed. The product of R_{load} and C_{load} must always be less than $T_{load,max}$.

D.2 Voltage Levels and Trip Points

D.2.1 V_{ih}–This is the input high voltage which a receiver must detect as an active state on bus (+) and as a passive state on bus (–).

D.2.2 V_{il}–This is the input low voltage which a transmitter must detect as an active state on bus (–) and as a passive state on bus (+).

D.2.3 V_{oh}–This is the output high voltage which a transmitter must drive bus (+) and the voltage which bus (–) must passively return to. Note that $V_{oh,min}$ is $V_{ih,min}$ plus the absolute maximum ground offset voltage ($V_{go,max}$).

D.2.4 V_{ol}–This is the output low voltage which a transmitter must drive bus (–) and the voltage which bus (+) must passively return to. Note that $V_{ol,max}$ is $V_{il,max}$ minus the absolute maximum ground offset voltage ($V_{go,max}$).

D.2.5 V_{og}–This is the absolute ground offset voltage that can exist between any two nodes on the network.

D.2.6 V_{sup}–This is the supply voltage which a transmitter must use to drive bus (+) and terminate bus (–).

D.2.7 V_{cm}–This is the receiver input common mode operating range. In order for the differential receiver to recognize a valid signal transition, the bus (+) and bus (–) signals must cross at a voltage within this range.

D.2.8 V_{hys}–This is the receiver hysteresis and overdrive voltage including any power supply reference tolerance.

D.2.9 R_{load}–This is the equivalent network resistance from each bus wire to the corresponding passive voltage source.

D.2.10 C_{load}–This is the equivalent network capacitance from each bus wire to ground.

D.2.11 T_{load}–This is the network time constant for each bus wire. This is the product of R_{load} and C_{load} of each bus wire. The time constant determines the maximum active-to-passive transition time.

D.2.12 T_t–This is the signal transition time for each bus wire from either the active-to-passive state or passive-to-active state. The passive-to-active edge is driven by the transmitter and shall be no more than $T_{t,max}$. The active-to-passive edge is determined by the network time constant, bus voltage levels, and the passive state supply voltage level.

D.2.13 C_{ulg}–This is the unit load node capacitance of each wire to ground. This capacitance, along with the unit load node capacitance wire-to-wire, results in the total network capacitance referred to in C.2.10.

D.2.14 C_{ulw}–This is the unit load node capacitance wire-to-wire. This capacitance along with the node capacitance of each wire to ground results in the total network capacitance referred to in C.2.10.

D.2.15 I_{leakA}–This is the leakage current of each wire when the bus is in the active state.

D.2.16 I_{leakPU}–This is the leakage current of each wire when the bus is in the passive state and the node is unpowered.

D.2.17 I_{leakPP}–This is the leakage current of each wire when the bus is in the passive state and the node is powered.

OMEGA EXHIBIT 2037

D.3 Input Voltage Limits—Given the Bus (+) Driver & Bus (–) Termination Supply Voltage (V_{sup}) and the maximum Receiver Hysteresis & Overdrive Voltage (V_{hys}), V_{ih} and V_{il} can be derived. (See Equations D1 through D4.)

$$V_{il,min} = \text{(Ground Reference)} - V_{go} = 0.00 - 1.00 = -1.00\ V \quad \text{(Eq. D1)}$$

$$V_{il,max} = ½\ (V_{sup,min}) - V_{hys,min} = ½\ (4.75) - 0.18 = 2.20\ V \quad \text{(Eq. D2)}$$

$$V_{ih,min} = ½\ (V_{sup,max}) + V_{hys,max} = ½\ (5.25) + 0.18 = 2.81\ V \quad \text{(Eq. D3)}$$

$$V_{ih,max} = V_{sup,max} + V_{go} = 5.25 + 1.00 = 6.25\ V \quad \text{(Eq. D4)}$$

where the ½ factor in $V_{il,max}$ and $V_{ih,min}$ assumes a receive comparator voltage level of one-half of the supply voltage. It turns out this is a good tradeoff for voltage ground offset capability versus output drive requirements.

D.4 Output Voltage Limits—Output voltage limits can be derived directly from the input voltage limits. (See Equations D5 through D8.)

$$V_{ol,min} = V_{il,min} + V_{go} = -1.00 + 1.00 = 0\ V\ \text{(Ground Reference)} \quad \text{(Eq. D5)}$$

$$V_{ol,max} = V_{il,max} - V_{go} = 2.20 - 1.00 = 1.20\ V \quad \text{(Eq. D6)}$$

$$V_{oh,min} = V_{ih,min} + V_{go} = 2.80 + 1.00 = 3.80\ V \quad \text{(Eq. D7)}$$

$$V_{oh,max} = V_{ih,max} - V_{go} = 6.25 - 1.00 = 5.25\ (V_{sup,max}) \quad \text{(Eq. D8)}$$

D.5 Network Time Constant & Signal Transition Time—In order to guarantee signal cross over in the Receiver Input Common Mode Operating Range (V_{cm}) the signal transition time must be less than 2.20 μs. This is $T_{t,max}$ + the worst case transition time from $V_{ol,min}$ to $V_{ol,max}$ for Bus (–), or $V_{oh,max}$ to $V_{oh,min}$ for Bus (+). Therefore, given $\Delta t = 2.20\ \mu s$, the following relationship for $V_{oh,min}$ must be satisfied for Bus (–) and $V_{ol,max}$ for Bus (+). (See Equations D9 through D12.)

$$V_{oh,min} = V_{sup,min}\ (1 - e^{-(\Delta t/Tload,max)}) \text{ for Bus (–)} \quad \text{(Eq. D9)}$$

$$V_{ol,max} = V_{oh,max}\ (e^{-(\Delta t/Tload,max)}) \text{ for Bus (+)} \quad \text{(Eq. D10)}$$

From this, the maximum network time constant ($T_{load,max}$) can be derived.

$$T_{load,max}(\text{Bus–}) = -\Delta t \div \ln(1-(V_{oh,min}/V_{sup,min})) \quad \text{(Eq. D11)}$$
$$= -2.20 \div \ln(1-(3.80/4.75)) = 1.37\ \mu s$$

$$T_{load,max}(\text{Bus+}) = -\Delta t \div \ln(V_{ol,max}/V_{oh,max})) \quad \text{(Eq. D12)}$$
$$= -2.20 \div \ln(1.20/5.25) = 1.49\ \mu s$$

Choosing a $T_{load,max}$ of 1.35 μs satisfies both equations. Given a maximum network time constant of 1.35 μs, the signal transition time $T_{t,max}$ can be found by subtracting the time from $V_{ol,min}$ to $V_{ol,max}$ (for Bus –) or the time from $V_{oh,max}$ to $V_{oh,min}$ (for Bus +) from 2.20 μs. (See Equations D13 through D16.)

Bus (–):

$$T(V_{ol,min} \text{ to } V_{ol,max}) = -T_{load,max} (\ln(1-(V_{ol,max}/V_{sup,min}))) \quad \text{(Eq. D13)}$$

$$= -1.35 (\ln(1-(1.20/4.75))) = 0.39\ \mu s$$

$$T_{load,max} = 2.20 - T(V_{ol,min} \text{ to } V_{ol,max}) \quad \text{(Eq. D14)}$$

$$= 2.20 - 0.39 = 1.81\ \mu s$$

Bus (+):

$$T(V_{oh,max} \text{ to } V_{oh,min}) = -T_{load,max} (\ln(V_{oh,min}/V_{oh,max})) \quad \text{(Eq. D15)}$$

$$= -1.35 (\ln(3.80/5.25))) = 0.44\ \mu s$$

$$T_{load,max} = 2.20 - T(V_{oh,max} \text{ to } V_{oh,min}) \quad \text{(Eq. D16)}$$

$$= 2.20 - 0.44 = 1.76\ \mu s$$

Therefore, choosing a network time constant $T_{load,max}$, of 1.35 μs and a signal transition time $T_{t,max}$ of 1.75 μs ensures that the two bus signals will cross within the Common Mode Operating Range.

Rationale– Not applicable.

Relationship of SAE Standard to ISO Standard– Not applicable.

Application– 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.

Reference Section

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

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

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

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

Developed by the SAE Vehicle Network for Multiplexing and Data Communications Standards Committee

CLASS B DATA COMMUNICATION NETWORK MESSAGES: DETAILED HEADER FORMATS AND PHYSICAL ADDRESS ASSIGNMENTS—SAE J2178/1 JUN92 SAE Recommended Practice

Report of the SAE Vehicle Network for Multiplexing and Data Communications Standards Committee approved June 1992.

TABLE OF CONTENTS

1. Scope
2. Reference and Related Documents, Terms, Definitions, Abbreviations, and Acronyms
2.1 Applicable Documents
2.1.1 SAE Publications
2.2 Terms and Definitions
2.3 Abbreviations and Acronyms
3. General Information
3.1 Part 1 Overview
3.2 In-Frame Response Field Formats
3.2.1 In-Frame Response Type 0
3.2.2 In-Frame Response Type 1
3.2.3 In-Frame Response Type 2
3.2.4 In-Frame Response Type 3
4. Single Byte Header Messages and Format
5. Consolidated Header Messages and Format
5.1 One Byte Form of the Consolidated Header Format
5.2 Three Byte Form of the Consolidated Header Format
5.2.1 Priority/Type—Byte 1
5.2.1.1 Priority (PPP Bits)
5.2.1.2 In-Frame Response (K Bit)
5.2.1.3 Addressing Type (Y Bit)
5.2.1.4 Type Modifier (ZZ Bits)
5.2.1.5 In-Frame Response (IFR) Types
5.2.2 Target Address—Byte 2
5.2.3 Source Address—Byte 3
6. Data Fields
6.1 Functional Data Field Formats
6.1.1 Functional Data Field Format 0
6.1.2 Functional Data Field Format 1
6.1.3 Functional Data Field Format 2
6.1.3.1 The Parameter/Quantity Bit "Q"
6.1.3.2 The Control Bit "C"
6.1.3.3 The Secondary Identification Address
6.1.4 Functional Data Field Format 3
6.1.5 Functional Data Field Format 4
6.2 Physical Data Field Formats
6.2.1 Physical Data Field Format 0
6.2.2 Physical Data Field Format 1
6.2.2.1 The Industry/Manufacturer Bit "I"
6.2.2.2 The Request/Response Bit "R"
6.2.2.3 The Test Mode Identification Reference
6.2.3 Physical Data Field Format 2
6.2.4 Physical Data Field Format 3
6.2.4.1 The Transfer Type Byte
6.2.4.2 The Block Length Bytes
6.2.4.3 The Starting Address Bytes
6.2.4.4 The Data Bytes
6.2.4.5 The Block Checksum Bytes
6.3 Extended Addressing
7. Physical Address Assignments
APPENDIX A
A.1 Architectures of Networks
A.2 Header Selection
APPENDIX B

1. Scope—This SAE Recommended Practice defines the information contained in the header and data fields of both diagnostic and non-diagnostic messages for automotive serial communications based on SAE J1850 Class B networks. This document describes and specifies the header fields, data fields, field sizes, scaling, representations, and data positions used within messages.

The general structure of a SAE J1850 message frame without in-frame response is shown in Figure 1. The structure of a SAE J1850 message with in-frame response is shown in Figure 2. Figures 1 and 2 also show the scope of frame fields defined by this document for non-diagnostic messages. Refer to SAE J1979 for specifications of emissions related diagnostic message header and data fields. Refer to SAE J2190 for the definition of other diagnostic message header and data fields. The description of the network interface hardware, basic protocol definition, the electrical specifications, and the CRC and Checksum fields (shown in the figures as ERR) are given in SAE J1850.

SAE J1850 defines two and only two formats of message headers. They are the Single Byte header format and the Consolidated header format. The consolidated header format has two forms, a single byte form and a 3 byte form. This document covers all of these formats and forms to identify the contents of messages which could be sent on a SAE J1850 network.

This document consists of four parts, each published separately.

Part 1 of SAE J2178 (this part, Titled: Detailed Header Formats and Physical Address Assignments) describes the two allowed forms of message header formats, single byte and consolidated. It also contains the physical node address range assignments for the typical sub-systems of an automobile. The details of this part are more fully described in paragraph 3.1 of this document.

Part 2 of SAE J2178 (Titled: Data Parameter Definitions) defines the standard parametric data which may be exchanged on SAE J1850 (Class B) networks. The parameter scaling, ranges, and transfer functions are specified.

Part 3 of SAE J2178 (Titled: Target Address for Single Byte Forms of Headers) defines the message assignments for the single byte header format and the 1 byte form of the consolidated header format.

Part 4 of SAE J2178 (Titled: Target Address (Second Byte) for Three Byte Headers) defines the message assignments for the second byte in the 3 byte form of the consolidated header format.

2. Reference and Related Documents, Terms, Definitions, Abbreviations, and Acronyms

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 J1213/1—Glossary of Vehicle Networks for Multiplex and Data Communication
SAE J1850—Class B Data Communication Network Interface
SAE J1930—Electrical/Electronic Systems Diagnostic Terms, Definitions, Abbreviations, and Acronyms
SAE J1979—E/E Diagnostic Test Modes
SAE J2190—Enhanced E/E Diagnostic Test Modes

2.2 Terms and Definitions

DATA [DATA FIELD]—Data and data field are used interchangeably in this document and they both refer to a field within a frame that may include bytes with parameters pertaining to the message and/or secondary ID and/or extended addresses and/or test modes which further defines a particular message content being exchanged over the network.

EXTENDED ADDRESS—The extended address is a means to allow a message to be addressed to a specific geographical location or zone of the vehicle, independent of any node's physical address.

FRAME—A frame is one complete transmission of information which

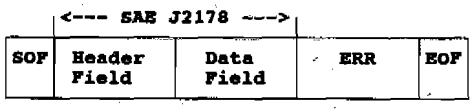


FIGURE 1—SCOPE OF SAE J2178 FOR A SAE J1850 FRAME WITHOUT IN-FRAME RESPONSE (IFR)

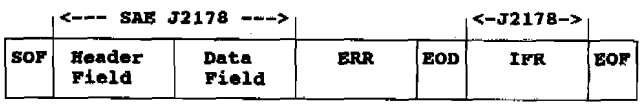


FIGURE 2—SCOPE OF SAE J2178 FOR A SAE J1850 FRAME WITH IN-FRAME RESPONSE (IFR)

may or may not include an In-Frame Response. The frame is enclosed by the start of frame and end of frame symbols. For Class B networks, each frame contains one and only one message (see "message" definition).

FUNCTIONAL ADDRESSING—Functional addressing allows a message to be addressed or sent to one or more nodes on the network interested in that function. Functional addressing is intended for messages that may be of interest to more than a single node. For example, an exterior lamp "off" message could be sent to all nodes controlling the vehicle exterior lamps by using a functional address. The functional address consists of a primary ID and may include a secondary ID.

HEADER [HEADER FIELD]—The header (or header field, used interchangeably) is a 1 or 3 byte field within a frame which contains information about the message priority, message source and target addressing, message type, and in-frame response type.

IN-FRAME RESPONSE (IFR) TYPE—The IFR type identifies the form of the in-frame response which is expected within that message.

LOAD—The load command indicates the operation of directly replacing the current/existing value of a parameter with the parameter value(s) contained in the message.

MESSAGE—A message consists of all of the bytes of a frame excluding the delimiter symbols (SOF, EOD, EOF, NB, IBS).

MODIFY—The modify command indicates the operation of using the message data parameter value to change (e.g., increment, decrement, or toggle) the current/existing value.

PARAMETER—A parameter is the variable quantity included in some messages. The parameter value, scaling, offset, units, transfer function, etc., are unique to each particular message. (The assigned parameters are contained herein.)

PHYSICAL ADDRESSING—Physical addressing allows a message to be addressed to a specific node or to all nodes or to a nonexistent, null node. The information in this message is only of relevance to a particular node, so the other nodes on the bus should ignore the message, except for the case of the "all nodes" address.

PRIMARY ID—The primary ID identifies the target for this functional message. This is the primary discriminator used to group functions into main categories.

PRIORITY—The priority describes the rank order and precedence of a message. Based upon the SAE J1850, Class B arbitration process, the message with the highest priority will win arbitration.

REPORT—A report indicates the transmission of parametric data values, based on: a change of state; a change of value; on a periodic rate basis; or as a response to a specific request.

REQUEST—A request is a command to, or a query for data, or action from another node on the network.

RESPONSE DATA—The response data is the information from a node on the network in response to a request from another node on the network. This may be an in-frame response or a report type of message.

SECONDARY ID—The secondary ID (along with the primary ID) identifies the functional target node for a message. The purpose of the secondary ID field within the frame is to further define the function or action being identified by the primary ID.

2.3 Abbreviations and Acronyms

CRC—Cyclic Redundancy Check
CS—Checksum
EOD—End of Data
EOF—End of Frame
ERR—Error Detection (CRC or CS)
IBS—Inter-Byte Separation
ID—Identifier
IFR—In-Frame Response
LSB—Least Significant Bit / Byte
MSB—Most Significant Bit / Byte
NB—Normalization Bit
PID—Parameter Identification number
SLOT—Scaling, Limit, Offset, and Transfer function
SOF—Start of Frame

3. General Information

3.1 Part 1 Overview—The messages defined by this four part document are specified for networks using single byte headers or consolidated 1 and 3 byte headers as specified in SAE J1850. Sections 4 and 5 of Part 1 provide the system architecture for the different possible headers used in Class B network communication (see Appendix A for supporting discussion). Section 6 of Part 1 defines the data fields used by the different header byte formats. Section 7 of Part 1 defines the physical address assignments.

Figure 3 shows an overview of this part (Part 1) which encompasses

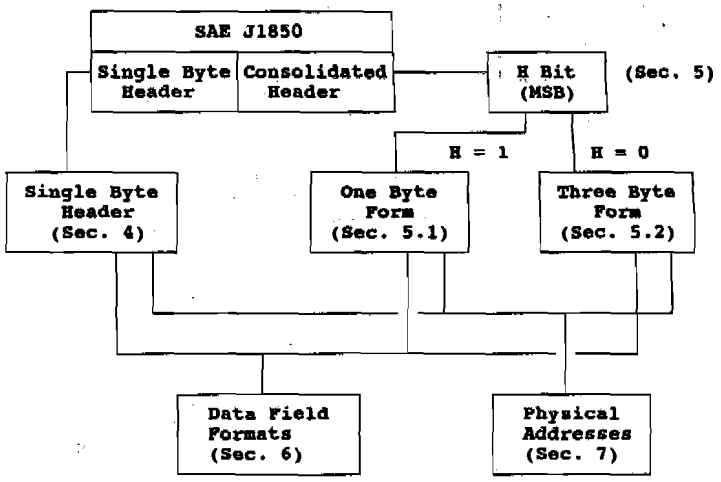


FIGURE 3—PART 1 OVERVIEW

the different possible messages and their component parts.

SAE J1850 defines two and only two formats of message headers. They are the Single Byte header format and the Consolidated header format. The consolidated header format has two forms, identified by the value of the H Bit. The two forms are: a 1 byte form and a 3 byte form. The information in the header field for both formats contains target, source, priority and message type information, while the data field contains additional addressing and/or parametric information and/or diagnostic test modes. This information is explicitly defined in some headers and implicitly defined in others. Messages defined by this document (Parts 1, 2, 3, and 4) are classified generally into two types:

a. Requests, that is, commands (load or modify) or queries for data, and

b. Responses, that is, reports or acknowledgements.

When a node generates a request, the target nodes which are responsible for the requested data or function must respond by reporting the requested information or by performing the requested function. For responses (that is, reports or acknowledgements), data information that a node responds with may have been previously requested by another node, or reported by the node when the desired information has changed, or reported by the node on a periodic basis.

Part 1 of this document describes the overall structure of messages. In total, parts 1, 2, 3, and 4:

a. Fully defines SAE (automotive industry) standard messages.
b. Reserves messages for future SAE standardization.
c. Reserves messages for manufacturers to allocate, which are typically unique or proprietary to that manufacturer.

In order to comply with this document, implementations need to use the defined messages on SAE J1850 networks in the exact way that they are defined here. However, there are a large number of message codes which are reserved for each manufacturer to independently allocate.

3.2 In-Frame Response Field Formats

3.2.1 IN-FRAME RESPONSE TYPE 0—The in-frame response type 0 is used to indicate the form without any in-frame response.

3.2.2 IN-FRAME RESPONSE TYPE 1—The in-frame response type 1 is a single byte response from a single responder. The response byte shall be the physical address of a receiver of the message. No CRC or CS checking byte is included for this response data.

3.2.3 IN-FRAME RESPONSE TYPE 2—The in-frame response type 2 is a single byte response from multiple responders. The response byte(s) shall be the physical address of the receiver(s) of the message. No CRC or CS checking is included for the response data.

3.2.4 IN-FRAME RESPONSE TYPE 3—The in-frame response type 3 is a multiple byte response from a single responder. The response bytes shall be data (generally not its address) from a single responder. The second CRC or CS checking byte is included for the data integrity of the response data. The actual in-frame response data shall be 1 byte in length, as a minimum.

4. Single Byte Header Messages and Format—For single byte header messages, the entire byte is used to define the message identifier (ID) as shown in Figure 4. Standard message identifiers that utilize this header

OMEGA EXHIBIT 2037

format are found in SAE J2178; Part 3. Single byte header messages use a checksum (CS) for data integrity.

All single byte header messages utilize one of the four in-frame response (IFR) types. These four types are illustrated as follows:

a. IFR Type 0—No response allowed. The number of data bytes cannot exceed ten. See Figure 5.

b. IFR Type 1—Single byte response from a single responder. The response byte is the physical address of a receiver of the message. No CS is included for the response data. The number of data bytes plus the single response byte cannot exceed ten. See Figure 6.

c. IFR Type 2—Single byte responses from multiple responders. The response byte(s) are the physical addresses of the receiver(s) of the message. No CS is included for the response data. The number of data bytes plus the "N" response bytes cannot exceed ten. See Figure 7.

d. IFR Type 3—Multiple byte response from a single responder. The response bytes are data from a single responder. A second CS is included for the data integrity of the response data. The number of data bytes, including the in-frame response (IFR) data, cannot exceed nine. The actual in-frame response data must be one byte in length, as a minimum. See Figure 8.

5. Consolidated Header Messages and Format—The consolidated header format includes both a 1 byte form and a 3 byte form. All consolidated header format messages use a CRC code for data integrity.

In order to accommodate a 1 byte header form and a 3 byte header form on the same network, bit 4 (H bit) in the first byte of the message has been defined to indicate the header form. This bit is defined in Table I.

TABLE 1—"H" BIT ASSIGNMENT

H Bit	Header Byte Form
0	3 Byte Form
1	1 Byte Form

5.1 One Byte Form of the Consolidated Header Format—The 1 byte form utilizes 7 bits for the message identifier (ID) and bit 4 (the H bit) = 1 to indicate the 1 byte form. Figure 9 illustrates this message header form. Standard message identifiers that utilize this header form are defined in SAE J2178; Part 3.

All 1 byte header form messages of the consolidated header format utilize one of the four in-frame response (IFR) types. These four types are illustrated as follows:

a. Type 0—No response allowed. The number of data bytes cannot exceed ten. See Figure 10.

b. IFR Type 1—Single byte response from a single responder. The response byte is the physical address of a receiver of the message. No CRC is included for the response data. The number of data bytes plus the single response byte cannot exceed ten. See Figure 11.

c. IFR Type 2—Single byte responses from multiple responders. The response byte(s) are the physical address of the receiver(s) of the message. No CRC is included for the response data. The number of data bytes plus the N response bytes cannot exceed ten. See Figure 12.

d. IFR Type 3—Multiple byte response from a single responder.

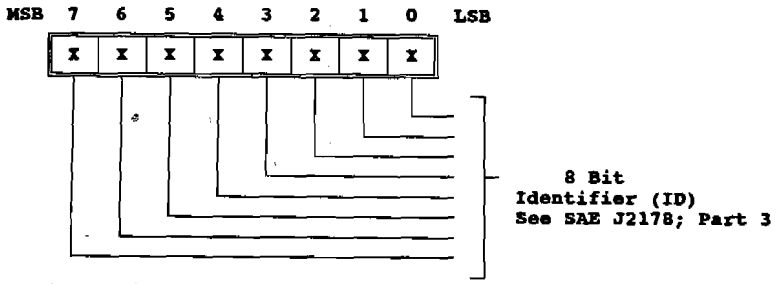


FIGURE 4—SINGLE BYTE HEADER FORMAT



FIGURE 5—SINGLE BYTE HEADER, IFR TYPE 0

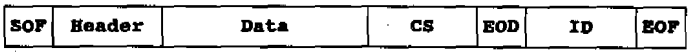


FIGURE 6—SINGLE BYTE HEADER, IFR TYPE 1

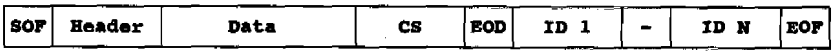


FIGURE 7—SINGLE BYTE HEADER, IFR TYPE 2

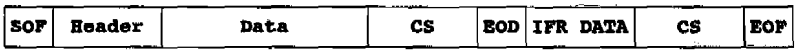


FIGURE 8—SINGLE BYTE HEADER, IFR TYPE 3

OMEGA EXHIBIT 2037

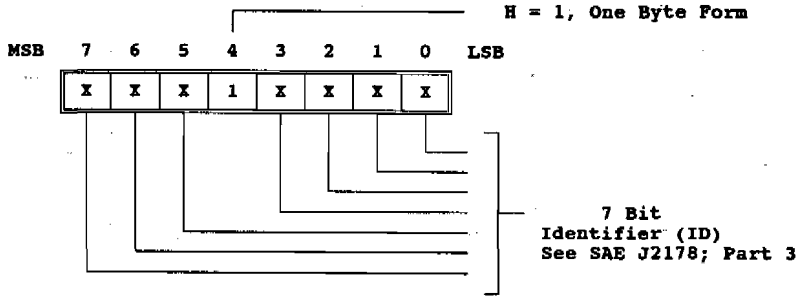


FIGURE 9—CONSOLIDATED HEADER, SINGLE BYTE FORM

SOF	Header	Data	CRC	EOF

FIGURE 10—ONE BYTE CONSOLIDATED HEADER, IFR TYPE 0

SOF	Header	Data	CRC	EOD	ID	EOF

FIGURE 11—ONE BYTE CONSOLIDATED HEADER, IFR TYPE 1

SOF	Header	Data	CRC	EOD	ID 1	-	ID N	EOF

FIGURE 12—ONE BYTE CONSOLIDATED HEADER, IFR TYPE 2

The response bytes are data from a single responder. The second CRC is included for the data integrity of the response data. The number of data bytes, including the in-frame response (IFR) data, cannot exceed nine. The actual in-frame response data must be 1 byte in length as a minimum. See Figure 13.

5.2 Three Byte Form of the Consolidated Header Format—This header form utilizes the first 3 bytes of the message. In this form, the "H" bit is a zero (0), signifying that the 3 byte header form is used for this message. The remaining 7 bits of the first byte contain information about priority and message type (KYZZ). The second byte contains the target address information. The target can be either functionally addressed or physically addressed. The third byte contains the physical address of the source of the message. Arbitration is always resolved by the end of the third byte, since the source address must be unique. Figure 14 illustrates the 3 byte header form.

5.2.1 PRIORITY/TYPE—BYTE 1—The priority/type byte contains information about priority, in-frame response, addressing type, and type modifier. Each of the field definitions are described in the following paragraphs.

5.2.1.1 *Priority (PPP Bits)*—The priority field is 3 bits in length which are the most significant bits of the first byte. The priority bit assignments are shown in Table 2.

5.2.1.2 *In-Frame Response (K Bit)*—The necessity for in-frame response is encoded into a single bit in the priority/type byte. This bit definition is shown in Table 3.

5.2.1.3 *Addressing Type (Y Bit)*—Message addressing is encoded with a single bit in the priority/type byte. This bit definition is shown in Table 4.

5.2.1.4 *Type Modifier (ZZ Bits)*—The type modifier is encoded as a 2 bit field and is used in conjunction with the in-frame response bit (K) and the address type bit (Y) to define sixteen message types, see Table 5.

5.2.1.5 *In-Frame Response (IFR) Types*—All 3 byte form messages of the consolidated header format listed in Table 5 utilize one of four in-frame response (IFR) types. These four types are illustrated as follows:

a. IFR Type 0—No response allowed. The number of data bytes cannot exceed eight. See Figure 15.

b. IFR Type 1—Single byte response from a single responder. The response byte is the physical address of a receiver of the message. No CRC is included for the response data. The number of data bytes plus the single response byte cannot exceed eight. See Figure 16.

c. IFR Type 2—Single byte responses from multiple responders. The response byte(s) are the physical address of the receiver(s) of the message. No CRC is included for the response data. The number of data bytes plus the N response bytes cannot exceed eight. See Figure 17.

d. IFR Type 3—Multiple byte response from a single responder. The response bytes are data from a single responder. The second CRC is included for the data integrity of the response data. The number of data bytes, including the in-frame response (IFR) data, cannot exceed seven. The actual in-frame response data must be 1 byte in length, as a minimum. See Figure 18.

5.2.2 TARGET ADDRESS—BYTE 2—The second byte of the 3 byte form of the consolidated header format contains either a functional or physical

SOF	Header	Data	CRC	EOD	IFR DATA	CRC	EOF

FIGURE 13—ONE BYTE CONSOLIDATED HEADER, IFR TYPE 3

OMEGA EXHIBIT

TABLE 2—PRIORITY FIELD ASSIGNMENTS

PPP Bits	Priority	
000	0	Highest
001	1	·
010	2	·
011	3	·
100	4	·
101	5	·
110	6	·
111	7	Lowest

TABLE 3—"K" BIT ASSIGNMENT

K Bit	In-Frame Response
0	Required
1	Not Allowed

TABLE 4—"Y" BIT ASSIGNMENT

Y Bit	Addressing Type
0	Functional
1	Physical

TABLE 5—THE SIXTEEN MESSAGE TYPES

H	PPP	KYZZ	Type Num.	Response (K)	Address Type (Y)	IFR Type	Message Type (Name)
0	XXX	0000	0	Required	Functional	2	Function
0	XXX	0001	1	Required	Functional	1	Broadcast
0	XXX	0010	2	Required	Functional	2	Function Query
0	XXX	0011	3	Required	Functional	3	Function Read
0	XXX	0100	4	Required	Physical	1	Node-to-Node
0	XXX	0101	5	Required	Physical	Reserved	Reserved - MFG.
0	XXX	0110	6	Required	Physical	Reserved	Reserved - SAE
0	XXX	0111	7	Required	Physical	Reserved	Reserved - MFG.
0	XXX	1000	8	Not Allowed	Functional	0	Function (Command/Status)
0	XXX	1001	9	Not Allowed	Functional	0	Function (Request/Query)
0	XXX	1010	10	Not Allowed	Functional	0	Function Extended (Command/Status)
0	XXX	1011	11	Not Allowed	Functional	0	Function Extended (Request/Query)
0	XXX	1100	12	Not Allowed	Physical	0	Node-to-Node
0	XXX	1101	13	Not Allowed	Physical	0	Block Transfer
0	XXX	1110	14	Not Allowed	Physical	0	Reserved - MFG.
0	XXX	1111	15	Not Allowed	Physical	0	Reserved - MFG.

NOTES

1. Functional Addresses for the 3 byte header form of header are defined in SAE J2178; Part 4. Physical Address Ranges are defined in Section 7.
2. Message types 8 and 9 use the functional data format #2 only; Message types 10 and 11 use the functional data format #3 only.
3. Reserved-SAE indicates reserved for future SAE Committee action. Reserved-MFG indicates that manufacturers are allowed to allocate these definitions without requiring any commonality between motor vehicle manufacturers.

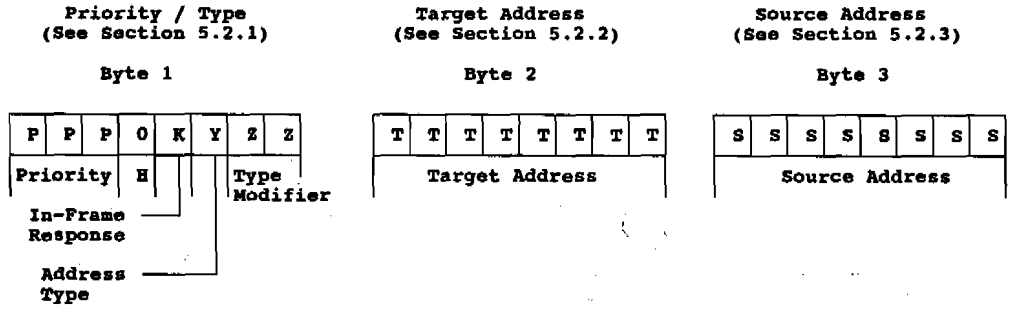


FIGURE 14—CONSOLIDATED HEADER, THREE BYTE FORM



FIGURE 15—THREE BYTE CONSOLIDATED HEADER, IFR TYPE 0

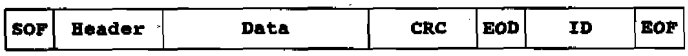


FIGURE 16—THREE BYTE CONSOLIDATED HEADER, IFR TYPE 1

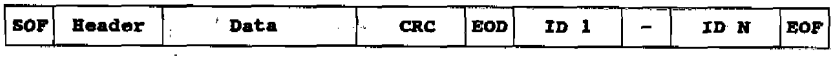


FIGURE 17—THREE BYTE CONSOLIDATED HEADER, IFR TYPE 2

target address. The physical address assignments are found in section 7 of this part, while functional message address assignments are in Part 4 (of SAE J2178).

5.2.3 SOURCE ADDRESS—BYTE 3—The third byte of the 3 byte format of the consolidated header format is the physical address of the source of the message. Physical address assignments are found in Section 7. These physical address assignments shall be unique for each node of a network.

6. Data Fields—In both message header formats, single byte and consolidated, the data field can usually be encoded in the same way. This section briefly describes the different ways that information can be formatted in the data field. The data field immediately follows the header field. The number of bytes in this field will vary, based upon the content of the header field. The maximum data field length is limited by the requirements of SAE J1850. Because of differences in functionally and physically addressed or with in-frame response data, these cases are defined separately.

6.1 Functional Data Field Formats

6.1.1 FUNCTIONAL DATA FIELD FORMAT 0—One of the functional data field formats is, in fact, no additional bytes of data (an empty data field). The message consists of the header, error checking byte, and in-frame response bytes. This is the format used for functional message types 2 and 3. Because the data field does not actually exist but to allow referencing in other parts of this document, it has been identified as the functional data field format 0.

6.1.2 FUNCTIONAL DATA FIELD FORMAT 1—In the simplest case including data (format 1), the data field contains only parametric data. The first byte of the data field in this case contains the most significant byte of data. The data field must contain 1 byte as a minimum. Figure 19 illustrates this message format. This data field format may be used for message types 0 and 1 only.

6.1.3 FUNCTIONAL DATA FIELD FORMAT 2—In a data field format 2 message, the data field contains a byte used as an identifier which further defines the target function being addressed. In this format type, the data field would appear as shown in Figure 20. This data format may be used for message types 0, 1, 8 and 9.

The secondary ID consists of a parameter / quantity bit Q (see 6.1.3.1) in which binary data (such as on/off or yes/no) can be encoded. There is a listing of the possible uses for this bit in other parts of this document. The control bit C (see 6.1.3.2) is used to distinguish between an immediate load of data or a modify of the current data for command messages. For message types 9 and 11, the control bit distinguishes between request and query. The remaining 6 bits specify an ID address (see 6.1.3.3). The order of these bits within the secondary ID byte is shown in Figure 21.

In many cases, a single data bit (the Q bit) is not adequate to define the parameter being sent. In this case, the identifier field is followed by a data field as illustrated in Figure 22. The combination of primary and secondary ID define if additional data is used by that message.

6.1.3.1 *The Parameter / Quantity Bit "Q"*—The parameter / quantity bit represents the data or information value for single, binary values. If the information being transmitted has one of two opposite values, it is reflected as shown in Table 6. The specific meaning or relevance of this bit is defined for each message in other parts of this document.

6.1.3.2 *The Control Bit "C"*—The control bit represents an action to be taken with the associated data values. Table 7 shows the two possible states for this bit. If the "C" bit indicates a load, the associated data value replaces the current/existing value. If the "C" bit indicates a modify or toggle, the current/existing data value is manipulated by the transmitted data value, based on the definition of each specific message (the 6 secondary identification address bits). For example, if the message indicates a toggle, the current/existing value is changed to the opposite state, independent of what that current/existing data value had been.



FIGURE 18—THREE BYTE CONSOLIDATED HEADER, IFR TYPE 3

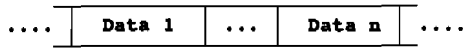


FIGURE 19—FUNCTIONAL DATA FIELD FORMAT 1



FIGURE 20—FUNCTIONAL DATA FIELD FORMAT 2

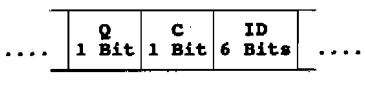


FIGURE 21—SECONDARY ID BYTE FORMAT

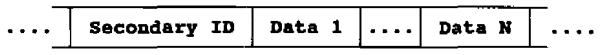


FIGURE 22—FUNCTIONAL DATA FIELD FORMAT 2, WITH DATA BYTES

OMEGA EXHIBIT 2037

TABLE 6—"Q" BIT ASSIGNMENT

Q Bit	Parameter/Quantity
0	No/False/Off/Down/..
1	Yes/True/On/Up/..

TABLE 7—"C" BIT ASSIGNMENT

C Bit	Command	Request/Query
0	Load	Request
1	Modify/Toggle	Query

For message types 9 and 11, the control bit distinguishes between request and query. The relevance of this bit is defined by the primary and secondary ID values and are specified in other parts of this document.

6.1.3.3 *The Secondary Identification Address*—The secondary identification address field is used to further identify the particular function or operation being addressed by this message. It is used to distinguish a function when the primary ID is not sufficient, or to define a specific operation to be performed by the function addressed by the primary ID. These secondary identification addresses are assigned in parts 3 and 4 of this document.

6.1.4 FUNCTIONAL DATA FIELD FORMAT 3—In a data field format 3 message, depending on the particular primary ID, the data field may also contain an extended address byte which defines the geographical location within the vehicle of the target function being addressed following the secondary ID byte. As an example, in a functional message whose primary ID target is window motion, an extended address byte is needed to identify which window, e.g., driver, passenger, all; along with the secondary ID byte needed to identify an operation such as Up or Down. This data field format may be used for message types 0 and 1 and must be used for message types 10 and 11. In this data field type, the data field appears as shown in Figure 23.

The extended address byte is used to determine where, geographically on a vehicle, a particular function is located. The exact definition of the extended address values can be found in 6.3. The secondary ID in Figure 23 is used as defined in 6.1.3. As an example, to roll the rear driver's side window down, the header would contain information that identifies window motion as the functional target. The first data byte would contain a 6-bit ID identifying the function Down with the Q-bit used to indicate enable the down or disable the down command, followed by the extended address, which would indicate that the particular window being addressed is on the rear driver's side. The C-bit is unused (default value = 0) in this particular message.

As in the other data field formats, a parameter data field may also be needed and in this case it is then appended to the end of the other identifiers. This format is shown in Figure 24.

6.1.5 FUNCTIONAL DATA FIELD FORMAT 4—In this data field format message, the data field contains a byte which defines the diagnostic test mode of the target function being addressed. In this type, the data field would appear as shown in Figure 25. This data format may be used for message types 0, 1, 8, and 9.

The test mode byte is used to determine which diagnostic function is involved. It may then be followed by a "Parameter Identification" (PID) number or other parameter data fields. In this case, the additional data bytes follow the test mode byte. This format is shown in Figure 26. This is the format for functionally addressed diagnostic messages such as those found in SAE J1979.

6.2 Physical Data Field Formats—The previous section (6.1) defined the data field formats for functionally addressed messages. This section (6.2) defines the data field formats for physically addressed messages.

6.2.1 PHYSICAL DATA FIELD FORMAT 0—One of the physical data field formats is, in fact, no additional bytes of data (an empty data field). The message consists of the header, error checking byte, and may be with or without in-frame response bytes. This is the format used for the acknowledgement message type. This message type simply confirms to another node that this node has correctly received the message it is acknowledging. Because this data field does not actually exist but to allow



FIGURE 23—FUNCTIONAL DATA FIELD FORMAT 3, WITH EXTENDED ADDRESS



FIGURE 24—FUNCTIONAL DATA FIELD FORMAT 3, WITH DATA BYTES

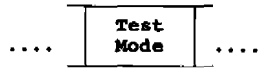


FIGURE 25—FUNCTIONAL DATA FIELD FORMAT 4

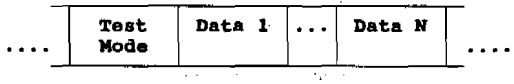


FIGURE 26—FUNCTIONAL DATA FIELD FORMAT 4, WITH DATA BYTES

referencing in other parts of this document, it has been identified as the physical data field format 0.

6.2.2 PHYSICAL DATA FIELD FORMAT 1—(Node to Node)

Physical data field format 1 is generally associated with the node-to-node message types. This message type is the one utilized for enhanced E/E diagnostic test modes (see SAE J2190).

This format assumes the 3 byte form of the consolidated header format. The single byte format and the 1 byte form of the consolidated header format are covered in physical data field format 2. Many of the specific diagnostic messages are defined in SAE J2190. This description of the format is consistent with that document but expands the definition to allow the format to be used in other messages as well. In particular, the manufacturer specific applications of this node-to-node message are expected to follow this format. The basic format is similar to the functional data field format 4. The format is shown in Figure 27.

The format will often include data bytes as shown in Figure 28. The content of the test mode byte indicates if additional data bytes are used.

The physical test mode byte details are shown in Figure 29. The description of the individual parts of this byte are described in the following paragraphs.

6.2.2.1 *The Industry/Manufacturer Bit "I"*—The industry/manufacturer bit represents the organization responsible for the definition of this test mode. The information that has been defined by SAE (I = 0) can be interpreted in the same way for all vehicles that use those definitions. The bit assignment is shown in Table 8. The specific meaning for the SAE (industry) messages are defined in SAE J2190. SAE has also reserved for future definition some of the I = 1 test mode bytes. Manufacturer defined test modes can be independently defined by each vehicle manufacturer and there is no attempt made to make these definitions common between manufacturers.

NOTE—See SAE J2190 for specific assignments.

6.2.2.2 *The Request/Response Bit "R"*—The request/response bit represents the direction of information flow contained in this message. Table 9 shows the two possible states for this bit. If the "R" bit indicates a request, the associated data bytes, if any, indicate the information being requested. If the "R" bit indicates a response, the data, if any, represent the response information previously requested.

6.2.2.3 *The Test Mode Identification Reference*—The test mode identification reference field is used to further identify the particular operation being addressed by this message. It is used to define a specific test mode to be performed by, or reported to, the node addressed by the target byte. These test mode identification addresses are assigned in SAE J2190 for the industry standard case.

6.2.3 PHYSICAL DATA FIELD FORMAT 2—(Diagnostic Test Modes)

TABLE 8—"I" BIT ASSIGNMENT

I Bit	Industry / Manufacturer
0	Industry (SAE Defined)
1	Industry (SAE Reserved/ Manufacturer Defined)

TABLE 9—"R" BIT ASSIGNMENT

R Bit	Request/Response
0	Request
1	Response

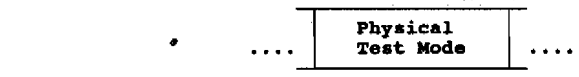


FIGURE 27—PHYSICAL DATA FIELD FORMAT 1

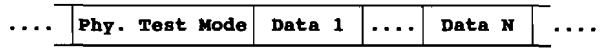


FIGURE 28—PHYSICAL DATA FIELD FORMAT 1, WITH DATA BYTES

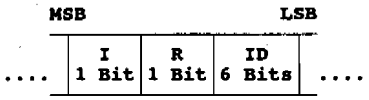


FIGURE 29—PHYSICAL TEST MODE BYTE FORMAT

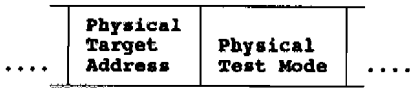


FIGURE 30—PHYSICAL DATA FIELD FORMAT 2

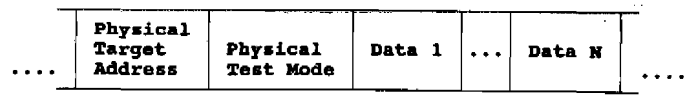


FIGURE 31—PHYSICAL DATA FIELD FORMAT 2, WITH DATA BYTES

OMEGA EXHIBIT 2037

In order to maximize commonality between the different header byte formats, the physical data field format 2 is essentially the same as for physical data field format 1 with the insertion of the physical target address byte ahead of the physical test mode byte. This allows the single byte header format and the 1 byte form of the consolidated header format to operate consistently with the 1 byte header form. The format is shown in Figures 30 and 31 for the two cases, with or without additional data bytes. The number of data bytes, if used, are not fixed length, unless so specified in other documents.

6.2.4 PHYSICAL DATA FIELD FORMAT 3—(Block Transfer)

This physical data field format is unique and dedicated to the transfer of large blocks of data from one physical node to another node of the network. It would have very limited application if it were restricted to the maximum message length requirements of SAE J1850. Therefore, this data format is allowed to exceed that limitation. The physical data field format 3 is shown in Figure 32.

Since the message length limitation of SAE J1850 has been extended, the data field format includes additional error checking bytes. Each group of bytes in this format is described in the following paragraphs.

NOTE—This format is normally limited to use for service diagnostics or module/vehicle manufacture. It should not normally be used during vehicle operation because of the potentially long interruption of other vehicle message traffic.

6.2.4.1 *The Transfer Type Byte*—The first byte of this physical data field format defines the type of block transfer that is being transmitted. The transfer type byte is reserved for future definition. It has been included as a place holder to allow future definition by SAE or manufacturers.

6.2.4.2 *The Block Length Bytes*—The next 2 bytes of this physical data field format define the length of the data block (N) included in the block. The value of N represents the number of data bytes, not the total number of bytes in the data field. The maximum value of N is 0FFF Hex for a data block maximum length of 4095 bytes. The upper nibble (upper 4 bits) of the MSB of the block length is thus reserved for future definition and should be set to zero as its default value.

6.2.4.3 *The Starting Address Bytes*—The next 3 bytes identify the starting address of the data block being transmitted. In other words, it is the memory location where data byte 1 is located. The other data bytes of the block (data 2 to data N) will then represent, sequentially, in ascending address order, the additional data bytes of the block.

6.2.4.4 *The Data Bytes*—The data itself contains from 1 to N data bytes being transferred between nodes.

6.2.4.5 *The Block Checksum Bytes*—Because the block length is most likely longer than most other messages on the network, additional error checking is required. The last 2 bytes are a calculated checksum value based on the contents of the data block only. The calculation begins with the first data byte (Transfer Type) and continues to the last data byte (data N). The checksum is a 16 bit sum of the values included. The general checksum calculation is comparable to the SAE J1850 checksum extended to 16 bits. The transmitted checksum should match the received, calculated checksum to verify correct reception.

NOTE—The header is not included in this checksum calculation.

NOTE—The data field described previously is followed by the error checking byte of the SAE J1850 format (ERR byte, CS or CRC) to verify the integrity of the whole message, the same as all other Class B messages.

6.3 Extended Addressing—The extended addressing defines an extended (geographical) location in the vehicle. The extended address field (RR XXX YYY) is divided into three sub-fields:

a. The two most significant bits (RR) are reserved for future use. (00 is the defined value for geographic location.)

b. The three next most significant bits (XXX) indicate rows from front (001) to rear (111).

TABLE 10—NODE PHYSICAL ADDRESS ASSIGNMENTS

Node	Address (Hex)
Powertrain Controllers:	
Integration / Manufacturer Expansion	00 - 0F
Engine Controller	10 - 17
Transmission Controller	18 - 1F
Chassis Controllers:	
Integration / Manufacturer Expansion	20 - 27
Brake Controller	28 - 2F
Steering Controller	30 - 37
Suspension Controller	38 - 3F
Body Controllers:	
Integration / Manufacturer Expansion	40 - 57
Restraints	58 - 5F
Driver Information / Displays	60 - 6F
Lighting	70 - 7F
Entertainment / Audio	80 - 8F
Personal Communications	90 - 97
HVAC	98 - 9F
Convenience (Doors, Seats, Windows, etc.)	A0 - BF
Security	C0 - C7
Future Expansion:	C8 - CF
Manufacturer Specific:	D0 - EF
Off-Board Testers / Diagnostic Tools:	F0 - FD
All Nodes:	FE
Null Node:	FF

c. The three least significant bits (YYY) indicate columns from left (001) to right (111).

The codes XXX = 000 (for rows) and YYY = 000 (for columns) indicate that ALL rows and/or ALL columns are indicated. In other words, to address all of the items in a specific row, regardless of which column, use XXX = 000. For all items in the same column, independent of which row, use YYY = 000. This can be useful if needed to address all headlamps, for example, to turn them all on, but for lamp outage, the particular location of the headlamp may be desirable.

A map illustrating 49 zones of the vehicle is shown in Figure 33. It generally represents a top view of the vehicle and supports both Left/Right and Driver/Passenger side references.

Appendix B shows some examples of this extended addressing as it identifies some common items in passenger vehicles.

7. Physical Address Assignments—The physical address assignment ranges for nodes on a network are shown in Table 10. It is important to note that node address assignments on any network must be unique. In other words, no two nodes can have the same physical address assignment.

NOTE—One address has been reserved to address all nodes on a network. The all nodes address, however, may or may not be recognized in a system. Additionally, one address has been reserved to address a "null node" which is never assigned to a real node. This "null node" allows some forms of testing network performance.

NOTE—The address ranges assigned to "Integration" are intended for modules which have more than one specific function. If this integration includes functions which involve crossing between Powertrain, Chassis, and Body, the highest priority (lowest address) range shall be selected, for example, if powertrain and chassis are integrated in one module, the 00 - 0F address range shall be used.

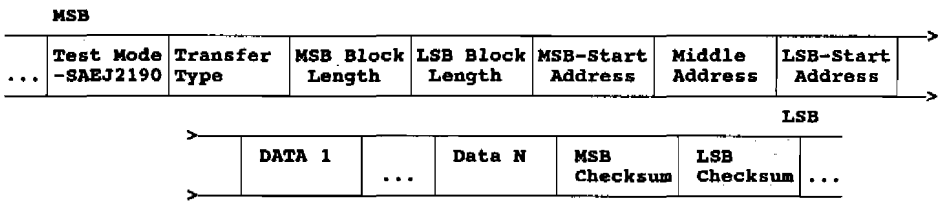


FIGURE 32—PHYSICAL DATA FIELD FORMAT 3—BLOCK TRANSFER

OMEGA EXHIBIT 2037

LEFT SIDE FRONT SURFACE (RR 001 001)	DRIVER'S SIDE FRONT SURFACE (RR 001 010)	LEFT CENTER FRONT SURFACE (RR 001 011)	CENTER POINT FRONT SURFACE (RR 001 100)	RIGHT CENTER FRONT SURFACE (RR 001 101)	PASSENGER SIDE FRONT SURFACE (RR 001 110)	RIGHT SIDE FRONT SURFACE (RR 001 111)
LEFT SIDE UNDER HOOD (RR 010 001)	DRIVER'S SIDE UNDER HOOD (RR 010 010)	LEFT CENTER UNDER HOOD (RR 010 011)	CENTER POINT UNDER HOOD (RR 010 100)	RIGHT CENTER UNDER HOOD (RR 010 101)	PASSENGER SIDE UNDER HOOD (RR 010 110)	RIGHT SIDE UNDER HOOD (RR 010 111)
LEFT SIDE AFT BULKHEAD (RR 011 001)	DRIVER'S SIDE AFT BULKHEAD (RR 011 010)	LEFT CENTER AFT BULKHEAD (RR 011 011)	CENTER POINT AFT BULKHEAD (RR 011 100)	RIGHT CENTER AFT BULKHEAD (RR 011 101)	PASSENGER SIDE AFT BULKHEAD (RR 011 110)	RIGHT SIDE AFT BULKHEAD (RR 011 111)
LEFT SIDE AFT "A" PILLAR (RR 100 001)	DRIVER'S SIDE AFT "A" PILLAR (RR 100 010)	LEFT CENTER AFT "A" PILLAR (RR 100 011)	CENTER POINT AFT "A" PILLAR (RR 100 100)	RIGHT CENTER AFT "A" PILLAR (RR 100 101)	PASSENGER SIDE AFT "A" PILLAR (RR 100 110)	RIGHT SIDE AFT "A" PILLAR (RR 100 111)
LEFT SIDE MID VEHICLE (RR 101 001)	DRIVER'S SIDE MID VEHICLE (RR 101 010)	LEFT CENTER MID VEHICLE (RR 101 011)	CENTER POINT MID VEHICLE (RR 101 100)	RIGHT CENTER MID VEHICLE (RR 101 101)	PASSENGER SIDE MID VEHICLE (RR 101 110)	RIGHT SIDE MID VEHICLE (RR 101 111)
LEFT SIDE TRUNK (RR 110 001)	DRIVER'S SIDE TRUNK (RR 110 010)	LEFT CENTER TRUNK (RR 110 011)	CENTER POINT TRUNK (RR 110 100)	RIGHT CENTER TRUNK (RR 110 101)	PASSENGER SIDE TRUNK (RR 110 110)	RIGHT SIDE TRUNK (RR 110 111)
LEFT SIDE REAR SURFACE (RR 111 001)	DRIVER'S SIDE REAR SURFACE (RR 111 010)	LEFT CENTER REAR SURFACE (RR 111 011)	CENTER POINT REAR SURFACE (RR 111 100)	RIGHT CENTER REAR SURFACE (RR 111 101)	PASSENGER SIDE REAR SURFACE (RR 111 110)	RIGHT SIDE REAR SURFACE (RR 111 111)

XXX = ROW -- FROM FRONT TO REAR 000 = ALL ROWS
YYY = COLUMN -- FROM SIDE TO SIDE 000 = ALL COLUMNS
RR = 00 (GEOGRAPHIC LOCATION)

FIGURE 33—EXTENDED ADDRESS MAP

APPENDIX A
NETWORK ARCHITECTURES AND HEADER SELECTION

A.1 Architectures of Networks—A wide variety of network topologies can be envisioned by network designers. The message structure described in this document is very flexible and useful in exchanging information between network nodes. The following discussion describes two network architectures which are likely configurations that can use this message definition set:

a. A single network architecture
b. A multiple network architecture

Which of the different message definitions to use for these two network architectures is left as the system designer's choice, since the selection would be application specific. It should be noted that the hardware that supports these two message structures is generally not interchangeable. It is recommended that care be taken in choosing which message definition to use because the selection is generally irreversible because of these hardware limitations.

Consideration must be given by the network designer as to whether a single network architecture or a multiple network architecture, within the same vehicle, is preferable for that application. For example, a multiple network architecture could be based on one network optimized around data communication (Class B) protocol requirements, and another network optimized around sensor type (Class A) multiplexing requirements. The Class B network may be characterized such that time is a significant characteristic of the protocol where the functional "broadcast" type of message strategy can most effectively be used. The functional messages strategy can, if required, define the source or destination of a particular message by making it part of the message. However, it is unnecessary to designate or specify the source or destination of functional broadcast type messages. Reception becomes the exclusive responsibility of the receiving node.

A Class A network could handle the vehicle's event-driven multiplexing requirements. See SAE J2057; Part 5, for more information on Class A multiplexing considerations. A single network architecture is based on the concept of a network which handles both Class A and B requirements. It should be clear that both network architectures must be cost effective for the application and the specific nodes on each network.

In Class B communications, the network consists of the interconnection of intelligent nodes such as: an engine controller, a body computer, a vehicle instrument cluster, and other modules. Such a network normally does not significantly reduce the base vehicle wiring but provides an inter-module data communications capability for distributed processing. The data shared between modules may be repetitive in nature and sometimes requires handshaking between modules or acknowledgement of data reception. As a result of handling the repetitive data and response type data, a network can be optimized around functional addressing. Functional addressing sends data on the network which can be received by one or more nodes without regard to the physical location of the module but only by their "interest" in those specific functions. In general, the transmitting node doesn't care which, if any, nodes receive the data it is sending. When physical addressing is required in a data communications (Class B) network, it is usually for vehicle diagnostic purposes and can be easily handled without reducing network bandwidth. See Section 6 for a discussion of these two types of message addressing.

In Class A communications, the network generally consists of the interconnection of limited intelligence nodes, often simply sensors or actuators. These Class A networks can significantly reduce the base vehicle wiring as well as potentially remove redundant sensors from the vehicle. The data shared between nodes in this case are generally event driven in nature. In most vehicles, the number of event driven signals predominate but are only needed infrequently. The message to "turn headlamps on," for example can be easily seen as event driven. Because these messages are infrequent (only sent once when the signal changes), they generally require acknowledgement, either within the same message or a separate handshake/response message. Both of these approaches are supported by SAE J1850 and in this document.

The single network architecture carries both the Class A and Class B messages on one network. The characteristics of both time critical and event driven messages must be accommodated on a message by message

OMEGA EXHIBIT

basis. In general, this level of complexity will need the flexibility of the consolidated header structure. For some applications, however, the single byte header may be adequate and is in no way limited by this specification.

The multiple network architecture tends to separate the Class A messages from the Class B messages and optimize each network and node interface for the specific characteristics of each network Class. The time critical messages could be exchanged on one network while the event driven messages sent on another. For example, the data communication (Class B) repetitive messages can be handled on one network and the sensor and control (Class A) multiplexing requirements on another network. This architecture requires both networks to work together to achieve the total vehicle network requirements. If information is needed between the multiple networks, care must be exercised to meet the needs of each of the networks. This concept of multiple networks is not limited to two, but can be extended to several separate networks, if desired.

A.2 Header Selection—The selection of headers is dependent on a number of factors. Hardware cost is related to the complexity of interface hardware required, as opposed to level of software required to implement the system. A CRC, for example, is most efficiently calculated in hardware. A Checksum (CS) is easily calculated in software.

The 3 byte form of the consolidated header offers systems designers advantages over the single byte only header format. More bits are available for use in assigning message identifiers, priorities, message types, etc. In addition, the 3 byte header is not restricted to 256 addresses. The most significant bit of the consolidated header format is used to indicate the use of 1 byte or 3 byte header messages which provides flexibility for future applications. This consolidated format generally requires increased hardware implementations because of the variety of message forms allowed. However, because of the increased hardware definition, software complexity and coding error problems are reduced. The consolidated header format offers the flexibility to readily handle both Class A and Class B requirements, matching header length to each specific message, as needed.

The single byte only header format is a simple and efficient method of identifying messages in a Class B data communications optimized network. This type of header can be simply called the Message Identifier or ID. The ID becomes the name of the message that is broadcast to all the other nodes on the network. The message ID concept supports a very easily understood message protocol leading to the utilization of a simple hardware interface circuit. The single byte only header format in a Class B data communications environment is required to support a repetitive message strategy and manage network bandwidth efficiently. The results can yield an average message length of less than 4 bytes. Message overhead can be kept small and message latency minimized to improve the network's capability for handling time critical data. Another resulting feature of this method of message identification is that arbitration events are reduced (resolved within the first byte) and the need to carefully assign message priority is reduced.

As in the case of network architectures above, the choice of single byte header format or consolidated header format is left to the system designer. The choice must be made for each separate network for each application but this offers the ability to select which characteristic is important for the specific case.

APPENDIX B
EXAMPLES OF EXTENDED ADDRESSING

B.1 Seat locations in the passenger compartment are shown in Figure B1.

B.2 Typical lighting locations and external access examples are shown in Figure B2.

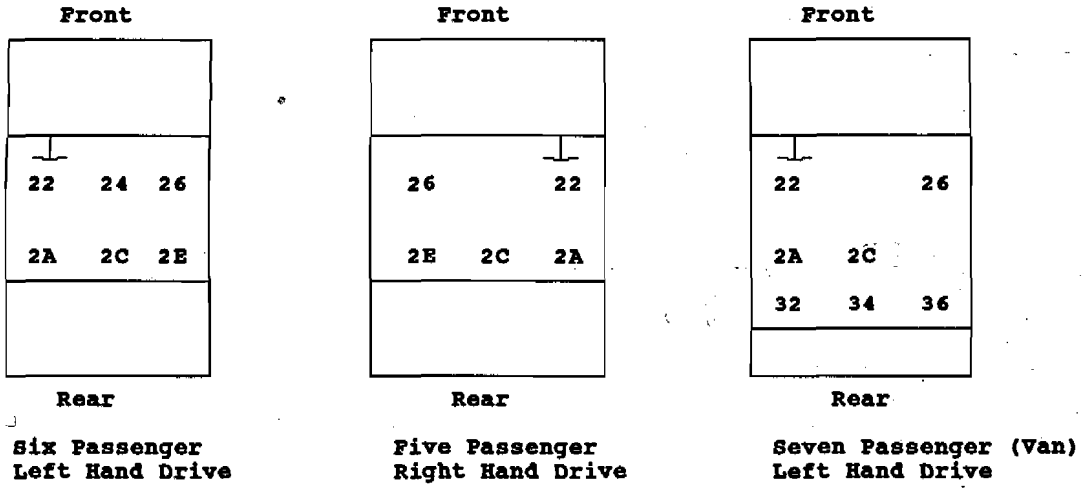


FIGURE B1—TYPICAL SEAT LOCATIONS

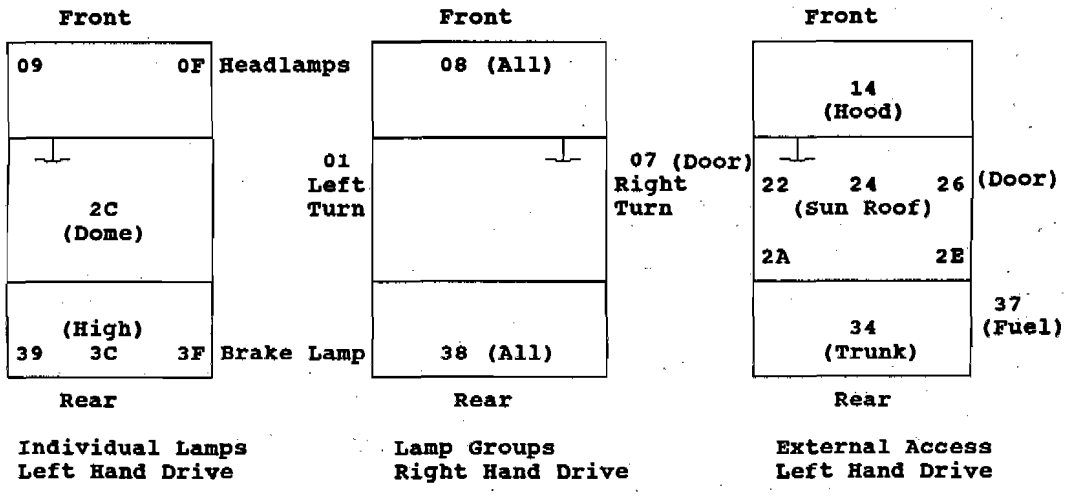


FIGURE B2—TYPICAL LIGHTING AND EXTERNAL ACCESS LOCATIONS

OMEGA EXHIBIT 2037

Report of the Vehicle Network for Multiplexing and Data Communications Standards Committee approved June 1993.

TABLE OF CONTENTS

1. Scope
1.1 Standardized Parameter Definitions
2. References
2.1 Applicable Documents
2.1.1 SAE Publications
2.1.2 ANSI Publication
2.2 Related Publications
2.3 Terms and Definitions
2.4 Abbreviations and Acronyms
3. General Information
3.1 Part 2 Overview
3.2 How To Use This Document
4. Parameter Reference Number (PRN) Structure
5. Parameter Formats
5.1 Bit Mapped Parameters
5.1.1 Bit Mapped Data Without Mask Byte(s)
5.1.2 Bit Mapped Data With Mask Byte(s)
5.1.3 Bit Values
5.2 Byte (8 Bit) Parameters
5.3 Word (16 Bit) Parameters
5.4 Multi-Byte (>16 Bit) Parameters
5.5 Multiple Parameter Packets
6. Specific Parameter (PRN) Assignments
6.1 Specific Parameters
7. Scaling, Limit, Offset, and Transfer Function (SLOT) Definitions
7.1 Multiple Parameter Packeted (PKT) SLOTs
7.1.1 Multiple Parameter Packeted Assignments
7.2 Bit Mapped Without Mask (BMP) SLOTs
7.2.1 Bit Mapped Without Mask Parameter Assignments
7.3 Bit Mapped With Mask Bytes (BMM) SLOTs
7.3.1 Bit Mapped With Mask Parameter Assignments
7.4 Unsigned Numeric (UNM) SLOTs
7.4.1 Unsigned Numeric Variable Assginments
7.5 2's Complement Signed Numeric (SNM) SLOTs
7.5.1 2's Complement Signed Numeric Variable Assignments
7.6 State Encoded (SED) SLOTs
7.6.1 State Encoded Variable Assignments
7.7 ASCII Encoded (ASC) SLOTs
7.7.1 ASCII Encoded Variable Assignments
7.7.2 ASCII Character Set
7.8 Binary Coded Decimal (BCD) SLOTs
7.8.1 Binary Coded Decimal (BCD) Variable Assignments
7.9 Signed Floating Point [Scientific Notation] (SFP) SLOT
7.9.1 Signed Floating Point Variable Assignment
8. Multiple Frame, Single Parameter Format

1. Scope—This SAE Recommended Practice defines the information contained in the header and data fields of non-diagnostic messages for automotive serial communications based on SAE J1850 Class B networks. This document describes and specifies the header fields, data fields, field sizes, scaling, representations, and data positions used within messages.

The general structure of a SAE J1850 message frame without in-frame response is shown in Figure 1. The structure of a SAE J1850 message with in-frame response is shown in Figure 2. Figures 1 and 2 also show the scope of frame fields defined by this document for non-diagnostic messages. Refer to SAE J1979 for specifications of emissions-related diagnostic message header and data fields. Refer to SAE J2190 for the definition of other diagnostic data fields. The description of the network interface hardware, basic protocol definition, the electrical specifications, and the CRC byte are given in SAE J1850.

SAE J1850 defines two and only two formats of message headers. They are the Single Byte header format and the Consolidated header format. The consolidated header format has two forms, a single byte form and a three byte form. This document covers all of these formats and forms to identify the contents of messages which could be sent on a SAE J1850 network.

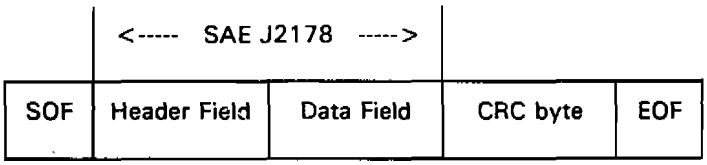


FIGURE 1—SCOPE OF SAE J2178 FOR A SAE J1850 FRAME WITHOUT IN-FRAME RESPONSE (IFR)

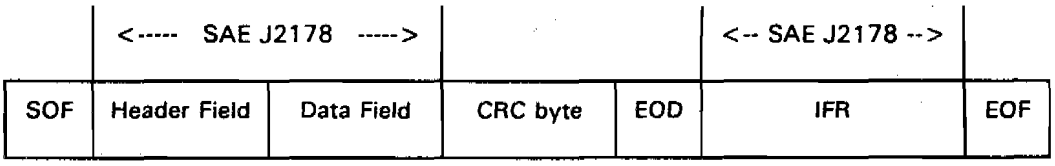


FIGURE 2—SCOPE OF SAE J2178 FOR A SAE J1850 FRAME WITH IN-FRAME RESPONSE (IFR)

This document consists of four parts, each published separately.

Part 1 of SAE J2178 (Titled: Detailed Header Formats and Physical Address Assignments) describes the two allowed forms of message header formats, single byte and consolidated. It also contains the physical node address range assignments for the typical subsystems of an automobile.

Part 2 of SAE J2178 (this part, Titled: Data Parameter Definitions) defines the standard parametric data which may be exchanged on SAE J1850 (Class B) networks. The parameter scaling, ranges, and transfer functions are specified. Messages which refer to these parametric definitions shall always adhere to these parametric definitions. It is intended that at least one of the definitions for each parameter in this part match the SAE J1979 definition. The details of this part are fully described in 3.1.

Part 3 of SAE J2178 (Titled: Frame IDs for Single Byte Forms of Headers) defines the message assignments for the single byte header format and the one byte form of the consolidated header format.

Part 4 of SAE J2178 (Titled: Message Definition for Three Byte Headers) defines the message assignments for the three byte form of the consolidated header format.

1.1 Standardized Parameter Definitions—The parameters used to describe data variables are one of the most important functions of this document. To achieve commonality of messages in Class B networks, the data parameters must become standardized. This applies to data parameter definitions for use during normal vehicle operations as well as during diagnostic operations. By using common parameter definitions for non-diagnostic and diagnostic functions on the network, the modules which form the network can maintain one image or description of a data parameter.

Where parameters have been defined in the Diagnostic Test Modes documents (SAE J1979 and J2190), such as Parameter Identifiers for diagnostic purposes, the definitions in Part 2 of this document match the diagnostic definition.

SAE J2178, Part 2 defines the parameters to be used for non-diagnostic and diagnostic data format definitions. For new parameter definitions which are needed in the future, the new definitions, if they are expected to become widely used, must be integrated into this document for commonality across these types of applications. Of course, manufacturers are free to assign their own definitions to data parameters which are unique or proprietary to their products. They are, however, restricted to using the "Manufacturer Reserved" message header assignments in Parts 3 and 4 of this document when using these unique or proprietary data parameter definitions.

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 J1850—Class B Data Communication Network Interface

SAE J1979—E/E Diagnostic Test Modes

SAE J2190—Enhanced E/E Diagnostic Test Modes

2.1.2 ANSI PUBLICATION—Available from ANSI, 11 West 42nd Street, New York, NY 10036-8002.

ANSI/IEEE Std 754-1985, August 12, 1985—IEEE Standard for Binary Floating-Point Arithmetic

2.2 Related Publications—The following publications are provided for information purposes only and are not a required part of this document.

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

SAE J1213/1—Glossary of Vehicle Networks for Multiplex and Data Communication

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

2.3 Terms and Definitions

2.3.1 DATA [DATA FIELD]—Data and data field are used interchangeably in this document and they both refer to a field within a frame that may include bytes with parameters pertaining to the message and/or secondary ID and/or extended addresses and/or test modes which further defines a particular message content being exchanged over the network.

2.3.2 EXTENDED ADDRESS—The extended address is a means to allow a message to be addressed to a specific geographical location or zone of the vehicle, independent of any node's physical address.

2.3.3 FRAME—A frame is one complete transmission of information which may or may not include an In-Frame Response. The frame is enclosed by the start of frame and end of frame symbols. For Class B networks, each frame contains one and only one message (see "message" definition).

2.3.4 FRAME ID—The Frame ID is the header byte for the Single Byte Header format and the one byte form of the consolidated header format. The definition of the frame ID is found in SAE J2178, Part 3. This header byte defines the target and source and content of the frame.

2.3.5 FUNCTIONAL ADDRESSING—Functional addressing allows a message to be addressed or sent to one or more nodes on the network interested in that function. Functional addressing is intended for messages that may be of interest to more than a single node. For example, an exterior lamp "off" message could be sent to all nodes controlling the vehicle exterior lamps by using a functional address. The functional address consists of a primary ID and may include a secondary ID and may also include an extended address.

2.3.6 HEADER [HEADER FIELD]—The header (or header field, used interchangeably) is a one or three byte field within a frame which contains information about the message priority, message source and target addressing, message type, and in-frame response type.

2.3.7 IN-FRAME RESPONSE (IFR) TYPE—The IFR type identifies the form of the in-frame response which is expected within that message.

2.3.8 LOAD—The load command indicates the operation of directly replacing the current/existing value of a parameter with the parameter value(s) contained in the message.

2.3.9 MESSAGE—A message consists of all of the bytes of a frame excluding the delimiter symbols (SOF, EOD, EOF, NB).

2.3.10 MODIFY—The modify command indicates the operation of using the message data parameter value to change (e.g., increment, decrement, or toggle) the current/existing value.

2.3.11 PARAMETER—A parameter is the variable quantity included in some messages. The parameter value, scaling, offset, units, transfer function, etc., are unique to each particular message. (The assigned parameters are contained herein.)

2.3.12 PHYSICAL ADDRESSING—Physical addressing allows a message to be addressed to a specific node or to all nodes or to a non-existent, null node. The information in this message is only of relevance to a particular node, so the other nodes on the bus should ignore the message, except for the case of the "all nodes" address.

2.3.13 PRIMARY ID—The primary ID identifies the target for this functional message. This is the primary discriminator used to group functions into main categories.

2.3.14 PRIORITY—The priority describes the rank order and precedence of a message. Based upon the SAE J1850, Class B arbitration process, the message with the highest priority will win arbitration.

2.3.15 REPORT—A report indicates the transmission of parametric data values, based on: a change of state; a change of value; on a periodic rate basis; or as a response to a specific request.

2.3.16 REQUEST—A request is a command to, or a query for data, or action from another node on the network.

2.3.17 RESPONSE DATA—The response data is the information from a node on the network in response to a request from another node on the network. This may be an in-frame response or a report type of message.

2.3.18 SECONDARY ID—The secondary ID (along with the primary ID or Frame ID) identifies the functional target node for a message. The purpose of the secondary ID field within the frame is to further define the function or action being identified by the primary ID.

2.4 Abbreviations and Acronyms

- A/C - Air Conditioning
- ASC - ASCII Encoded SLOT
- BCD - Binary Coded Decimal (BCD) SLOT
- BMM - Bit Mapped with Mask SLOT
- BMP - Bit Mapped without Mask SLOT
- CRC - Cyclic Redundancy Check
- CS - Checksum
- DTC - Diagnostic Trouble Code
- EOD - End of Data
- EOF - End of Frame
- ERR - Error Detection
- HVAC - Heating, Ventilation, Air Conditioning
- ID - Identifier
- IFR - In-Frame Response
- LSB - Least Significant Bit/Byte
- MSB - Most Significant Bit/Byte
- NB - Normalization Bit
- PID - Parameter IDentification (number, NOT the primary ID, See Section 6)
- PKT - Multiple Parameter Packet SLOT
- PRN - Parameter Reference Number
- SED - State Encoded SLOT
- SFP - Signed Floating Point (Scientific Notation) SLOT
- SLOT - Scaling, Limit, Offset, and Transfer Function (See Section 7)
- SNM - 2's Complement Signed Numeric SLOT
- SOF - Start of Frame
- UNM - Unsigned Numeric SLOT
- VIN - Vehicle Identification Number

3. General Information

3.1 Part 2 Overview—Section 4 provides a description of the parameter reference number (PRN) number groupings used for assigning PRN numbers to

OMEGA EXHIBIT 2037

individual parameters. Section 5 defines the formats used to define all standard parameters to be used in SAE J2178 messages. Section 6 defines the specific parameter assignments in terms of names, units, and scale factor reference. Section 7 defines the actual parameter specifications (SLOT), in terms of the length, bit resolution, range, scale factor details, etc. Section 8 describes the case of very long parameters which cannot be transmitted in a single message. Appendix A provides a numerical cross reference to assist in finding the correct name of a parameter if the parameter identification number is known. Appendix B is an alphabetical cross reference to assist in finding the correct parameter identification number if the parameter name is known.

The messages contain header fields and data fields, described in Part 1 of SAE J2178. The header field contains target, source, priority, and message type information, while the data field contains optional additional addressing and parametric information. This document defines the parametric information.

For some applications, it is desirable to include multiple parameters in a single message. The multiple parameter format is called a packet in this document. For example, some diagnostic messages consist of combinations of these parameters to improve information density or to insure simultaneous readings of different variables. A very limited set of these combinations are defined here as industry standards but individual manufacturers are free to use this form in manufacturer specific messages, as needed.

3.2 How To Use This Document—This part (Part 2 of SAE J2178) provides the definition of parameters which are commonly found, or could be expected in vehicle Electrical/Electronic Systems today. These parameters have been defined to allow messages on a Class B communication system to have consistent meaning between manufacturers and over time. The parameter definition consists of two parts, the "PRN" and the "SLOT." The "PRN" (Parameter Reference Number) is a number used to identify a specific parameter by name, unit of measure, and its associated "SLOT." The "SLOT" defines the mathematical characteristics of parameters in terms of its representation (Binary, Unsigned Numeric, ASCII, BCD, etc.), its scaling (1 Bit =), its limits and offsets, and its transfer function.

To find a parameter by name or PRN number, Appendices A and B provide cross references to the page of this document where the PRN can be found. The PRN numbers have also been grouped by subsystem to enable the reader to look for parameters if the name is not known.

If the parameter has not as yet been included in the list of PRNs, users can define new parameters in terms of the SLOTs which have been defined.

4. Parameter Reference Number (PRN) Structure—Parameter Reference Numbers (PRNs) are used to simplify documentation. They do not, in themselves, have particular significance. PRNs do allow simplification of reference, particularly for diagnostic purposes. To this end, a structure for PRN number assignments has been developed. The structure is described in the following paragraphs. Some of the PRN numbers are assigned or reserved for SAE definitions but the majority are reserved for individual motor vehicle manufacturers to coordinate and assign.

All PRN addresses are two bytes long, with the first byte identifying a grouping or classification reference (refer to Tables 1 and 2). The second byte is then a sequence number pointing to the specific parameter used (refer to Tables 4 through 19). There has not been any attempt made to group or commonize the meaning in the second byte. The specific assignments are found in Section 6. Note that all PRN addresses are listed as hexidecimal numbers throughout this document.

SAE J1979 refers to PID numbers which are a single byte reference number. The first 256 PRNs defined here (first byte = 00), are identical with the SAE J1979 PID definitions.

Figure 3 shows the basic structure of PRNs and Tables 1 and 2 show bit assignments and address ranges based on these assignments.

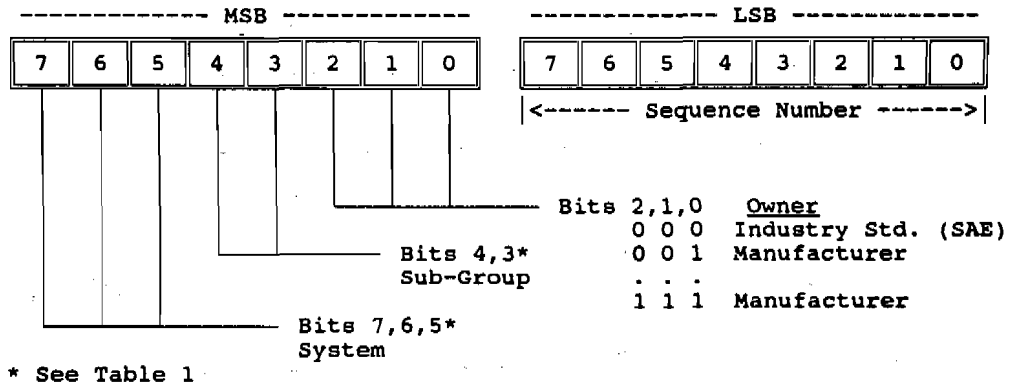


FIGURE 3—PRN STRUCTURE

5. Parameter Formats—Parameter values are represented in bit, byte, word, and multi-byte forms. The length of the parameter is uniquely associated with the message header and any included secondary ID field. These parameter definitions are referenced by one or more messages. The parameters allow a wide variety of variables, data definitions,and representations to provide the ability to use this definition for all messages, even when the industry standard messages are not useful for particular applications.

5.1 Bit Mapped Parameters—The bit mapped parameters, that is, those which have only two logical values (for example: True/False), are handled in one of two ways. The "Q" bit described in Section 6 of Part 1 of SAE J2178, is used if there is only one bit of information. In many cases, however, the bit values are associated together and form byte groupings, generally around common functional characteristics. Bit mapped data are transmitted either with or without corresponding mask bytes as described as follows.

5.1.1 BIT MAPPED DATA WITHOUT MASK BYTE(S)—In some cases, such as configuration identification, there is information which can be grouped as binary bits which represent whether, for example, a function or test is supported in a system. This form does not allow the bits to be supplied from different nodes in the network. If the bits potentially come from more than one node, the form with mask bytes described in 5.1.2, is used. The general form of the bit data bytes without mask is shown in Figure 4.

For these bit data cases, the bit names (that is: items) are somewhat different to emphasize the difference in format. These names are shown in Figure 5. If there is more than one byte of data of this form, the item numbers are incremented by one, sequentially, beginning at one from the MSB of the first byte.

For definition purposes, it is also possible to describe a single or multiple bit group which is smaller than a byte but which are combined into a byte or multiple bytes when the complete message is defined. This is a convenience used in this document to define some parameters. This definition notation applies equally to byte(s) with or without masks.

5.1.2 BIT MAPPED DATA WITH MASK BYTE(S)—For bit mapped data value groups that may come from several nodes or may not be valid for an application, a special format has been defined. Figures 6 and 7 show the data byte formats used. The data format allows two options in the number of bits in a group; 8 or 16. Since the defined bits for such groupings may not always come from a single network node, the format includes mask bytes indicating if an individual bit is valid for this message or if it should be ignored. The mask bytes map directly to the data bits with which they are associated. Figures 8 and 9 show how these bits are mapped within each byte. Table 3 shows the bit value for the mask bits.

OMEGA EXHIBIT 2037

TABLE 1—PRN GROUPINGS

7 6 5	System	4 3	Subgroup	Address (Hex)
0 0 0	Powertrain	0 0	J1979 Compatible	0000-00FF
		0 0	Reserved	0100-07FF
		0 1	Reserved	0800-0FFF
		1 0	Engine	1000-17FF
		1 1	Transmission	1800-1FFF
0 0 1	Chassis	0 0	Reserved	2000-27FF
		0 1	Brakes/Tires/Wheels	2800-2FFF
		1 0	Steering	3000-37FF
		1 1	Suspension	3800-3FFF
0 1 0	Body 1	0 0	Reserved	4000-47FF
		0 1	Reserved	4800-4FFF
		1 0	Reserved	5000-57FF
		1 1	Restraints	5800-5FFF
0 1 1	Body 2	0 0	Driver Info.	6000-67FF
		0 1	Reserved	6800-6FFF
		1 0	Lighting	7000-77FF
		1 1	Reserved	7800-7FFF
1 0 0	Body 3	0 0	Audio	8000-87FF
		0 1	Reserved	8800-8FFF
		1 0	Pers. Comm.	9000-97FF
		1 1	HVAC	9800-9FFF
1 0 1	Body 4	0 0	Convenience	A000-A7FF
		0 1	Reserved	A800-AFFF
		1 0	Reserved	B000-B7FF
		1 1	Reserved	B800-BFFF
1 1 0	Other 1	0 0	Security	C000-C7FF
		0 1	Reserved	C800-CFFF
		1 0	Reserved	D000-D7FF
		1 1	Reserved	D800-DFFF
1 1 1	Other 2	0 0	Config. Codes	E000-E7FF
		0 1	Reserved	E800-EFFF
		1 0	Tester/Diag.	F000-F7FF
		1 1	Miscellaneous	F800-FFFF

. . .	Data Byte 1	. . .	Data Byte N	. . .

FIGURE 4—BIT DATA FIELD WITHOUT MASK FORMAT

	MSB							LSB	
. . .	Bit 7 Item 1	Bit 6 Item 2	Bit 5 Item 3	Bit 4 Item 4	Bit 3 Item 5	Bit 2 Item 6	Bit 1 Item 7	Bit 0 Item 8	. . .

FIGURE 5—BITS WITHOUT MASK BYTE

. . .	Data Byte	Mask Byte	. . .

FIGURE 6—FORMAT FOR 8-BIT DATA WITH MASK

. . .	Data Byte 1	Mask Byte 1	Data Byte 2	Mask Byte 2	. . .

FIGURE 7—FORMAT FOR 16-BIT DATA WITH MASK

	MSB							LSB	
. . .	Bit 7 Item 1	Bit 6 Item 2	Bit 5 Item 3	Bit 4 Item 4	Bit 3 Item 5	Bit 2 Item 6	Bit 1 Item 7	Bit 0 Item 8	. . .

FIGURE 8—BIT MAPPED DATA BYTE

TABLE 2—SAE/MFG PRN RANGES

System	Subgroup	Address Map	Size
Powertrain	J1979 Compatible - SAE	0000 - 00FF	0.25K
	Reserved - MFG	0100 - 07FF	1.75K
	Reserved - SAE	0800 - 08FF	0.25K
	Reserved - MFG	0900 - 0FFF	1.75K
	Engine - SAE	1000 - 10FF	0.25K
	Engine - MFG	1100 - 17FF	1.75K
	Transmission - SAE	1800 - 18FF	0.25K
	Transmission - MFG	1900 - 1FFF	1.75K
Chassis	Reserved - SAE	2000 - 20FF	0.25K
	Reserved - MFG	2100 - 27FF	1.75K
	Brakes/Tires/Wheels - SAE	2800 - 28FF	0.25K
	Brakes/Tires/Wheels - MFG	2900 - 2FFF	1.75K
	Steering - SAE	3000 - 30FF	0.25K
	Steering - MFG	3100 - 37FF	1.75K
	Suspension - SAE	3800 - 38FF	0.25K
	Suspension - MFG	3900 - 3FFF	1.75K
Body 1	Reserved - SAE	4000 - 40FF	0.25K
	Reserved - MFG	4100 - 47FF	1.75K
	Reserved - SAE	4800 - 48FF	0.25K
	Reserved - MFG	4900 - 4FFF	1.75K
	Reserved - SAE	5000 - 50FF	0.25K
	Reserved - MFG	5100 - 57FF	1.75K
	Restraints - SAE	5800 - 5800	0.25K
	Restraints - MFG	5900 - 5FFF	1.75K
Body 2	Driver Information - SAE	6000 - 60FF	0.25K
	Driver Information - MFG	6100 - 67FF	1.75K
	Reserved - SAE	6800 - 68FF	0.25K
	Reserved - MFG	6900 - 6FFF	1.75K
	Lighting - SAE	7000 - 70FF	0.25K
	Lighting - MFG	7100 - 77FF	1.75K
	Reserved - SAE	7800 - 78FF	0.25K
	Reserved - MFG	7900 - 7FFF	1.75K
Body 3	Audio - SAE	8000 - 80FF	0.25K
	Audio - MFG	8100 - 87FF	1.75K
	Reserved - SAE	8800 - 88FF	0.25K
	Reserved - MFG	8900 - 8FFF	1.75K
	Personal Communications - SAE	9000 - 90FF	0.25K
	Personal Communications - MFG	9100 - 97FF	1.75K
	HVAC - SAE	9800 - 98FF	0.25K
	HVAC - MFG	9900 - 9FFF	1.75K
Body 4	Convenience - SAE	A000 - A0FF	0.25K
	Convenience - MFG	A100 - A7FF	1.75K
	Reserved - SAE	A800 - A8FF	0.25K
	Reserved - MFG	A900 - AFFF	1.75K
	Reserved - SAE	B000 - B0FF	0.25K
	Reserved - MFG	B100 - B7FF	1.75K
	Reserved - SAE	B800 - B8FF	0.25K
	Reserved - MFG	B900 - BFFF	1.75K
Other 1	Security - SAE	C000 - C0FF	0.25K
	Security - MFG	C100 - C7FF	1.75K
	Reserved - SAE	C800 - C8FF	0.25K
	Reserved - MFG	C900 - CFFF	1.75K
	Reserved - SAE	D000 - D0FF	0.25K
	Reserved - MFG	D100 - D7FF	1.75K
	Reserved - SAE	D800 - D8FF	0.25K
	Reserved - MFG	D900 - DFFF	1.75K
Other 2	Configuration Codes - SAE	E000 - E0FF	0.25K
	Configuration Codes - MFG	E100 - E7FF	1.75K
	Reserved - SAE	E800 - E8FF	0.25K
	Reserved - MFG	E900 - EFFF	1.75K
	Tester/Diagnostics - SAE	F000 - F0FF	0.25K
	Tester/Diagnostics - MFG	F100 - F7FF	1.75K
	Miscellaneous - SAE	F800 - F8FF	0.25K
	Miscellaneous - MFG	F900 - FFFF	1.75K

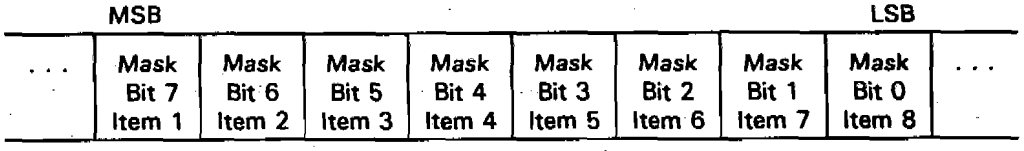


FIGURE 9—BIT MAPPED MASK BYTE

TABLE 3—MASK BIT ASSIGNMENT

Mask Bit	Bit Mapped Masking
0	Not A Valid Bit
1	Valid Bit

5.1.3 BIT VALUES—The general form of binary data is that 1 = true and 0 = false. One bit can carry a wide variety of interpretations, depending on the subject that it describes.

5.2 Byte (8 Bit) Parameters—Data parameters which can be expressed in 8 bits or less are expressed in a byte format. Byte parameters are the most common format. Figure 10 shows this format.

5.3 Word (16 Bit) Parameters—Data parameters which can be expressed in 9 to 16 bits are expressed in word format with the most significant byte transmitted first (high byte/low byte). Figure 11 shows this format.

5.4 Multi-Byte (>16 Bit) Parameters—Data parameters which can be expressed in more than 16 bits are expressed in multi-byte format with the most significant byte transmitted first (highest byte /.../ lowest byte). Figure 12 shows this format.

5.5 Multiple Parameter Packets—It is often useful to group parameters together into a packet to increase the information density of messages. For example, sending a fluid level and maximum capacity value in the same message, or a packet of single bit(s) or multiple bit definitions that may be smaller than a full byte, can be combined in this way. Parameter packets will be defined in this document in the same way as any other parameter, having a packet PRN number and SLOT reference assignment. If bit mapped parameters are included in a packet, the bit mapped byte(s) and the associated mask byte(s) are grouped together as a set representing a parameter. Thus, the data bytes and mask bytes for each parameter are together within the packet. Note that packets may be made of other packets, but each will be uniquely defined by combining each subpart into a message. Figure 13 shows the general form of a parameter packet.

A few examples, such as some of the SAE J1979 compatible PRN definitions in Section 6 will make this format clear.



FIGURE 10—BYTE PARAMETERS

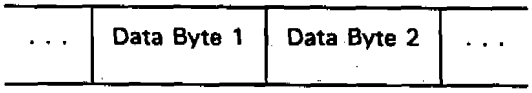


FIGURE 11—WORD PARAMETERS



FIGURE 12—MULTI-BYTE PARAMETERS



FIGURE 13—MULTIPLE PARAMETER PACKETS

6. Specific Parameter (PRN) Assignments—This section defines industry standard parameters used in messages found in parts 3 and 4. These parameters have been listed in random order based on when they were defined. Note that any PRN address in the SAE range that is not currently defined is reserved for SAE use. Cross references are provided in Appendices A and B of this part of SAE J2178 to assist the reader in finding the specific definition for each parameter.

6.1 Specific Parameters—The following definitions include the Parameter Reference Number (PRN), parameter name, units of measure, and associated SLOT number. The SLOT number is a reference to the Scaling, Limit, Offset, and Transfer function (SLOT) definition found in Section 7 as follows. The SLOT reference numbers have a format of: F-N-#, where F is a three-letter mnemonic indicating the format code type (see Section 7), N is the number of bits in the parameter, and # is the sequence number for that type of

SLOT. There is no relationship between sequence numbers for different format codes or number of bytes. Note that the sequence number is randomly assigned. Decimal sequence numbers of 1000 and above are available for manufacturers to assign. All SAE-assigned sequence numbers will be in the range from 1 to 999 exclusively and are not to be used by manufacturers. The sequence number ZERO (0) has the special purpose of a fill sequence which is used in packet definitions. The ZERO sequence number is all zeros, for the number of bits specified. The Parameter Reference Numbers (PRNs) are the index reference used by the message definitions found in Parts 3 and 4 of this document. The specific parameters are grouped as follows:

- Table 4 - SAE J1979 Compatible PRN Assignments
- Table 5 - Engine PRN Assignments
- Table 6 - Transmission PRN Assignments
- Table 7 - Brakes/Tires/Wheels PRN Assignments
- Table 8 - Steering PRN Assignments
- Table 9 - Suspension PRN Assignments
- Table 10 - Restraints PRN Assignments
- Table 11 - Driver Information PRN Assignments
- Table 12 - Lighting PRN Assignments
- Table 13 - Audio PRN Assignments
- Table 14 - Personal Communication PRN Assignments
- Table 15 - HVAC PRN Assignments
- Table 16 - Convenience PRN Assignments
- Table 17 - Security PRN Assignments
- Table 18 - Configuration Codes PRN Assignments
- Table 19 - Tester/Diagnostics PRN Assignments
- Table 20 - Miscellaneous PRN Assignments

TABLE 4—SAE J1979 COMPATIBLE PRN ASSIGNMENTS
(PRNs 0000 - 00FF)

PRN	Parameter Name	Resolution (1 Bit =)	Units Of Measure	Slot # (F-N-#)
0000	PIDs Supported (01h - 20h)	-	Bit Mapped	BMP-32-1
0001	Number of Emission-Related Trouble Codes & MIL Status	-	Packeted	PKT-32-1
0002	Trouble Code That Caused Freeze Frame Storage	-	Packeted	PKT-16-1
0003	Fuel System Status	-	Packeted	PKT-16-2
0004	Calculated Load Value	100/255	% Full Load	UNM-08-61
0005	Engine Coolant Temperature	1	Degrees Centigrade	UNM-08-102
0006	Short Term Fuel Trim - Bank 1	100/128	% Enrichment	UNM-08-92
0007	Long Term Fuel Trim - Bank 1	100/128	% Enrichment	UNM-08-92
0008	Short Term Fuel Trim - Bank 2	100/128	% Enrichment	UNM-08-92
0009	Long Term Fuel Trim - Bank 2	100/128	% Enrichment	UNM-08-92
000A	Fuel Pressure (Gage)	3	kPaG	UNM-08-131
000B	Intake Manifold Absolute Pressure	1	kPaA	UNM-08-101
000C	Engine RPM - High Resolution	1/4	RPM	UNM-16-31
000D	Vehicle Speed - Low Resolution - Metric	1	km/h	UNM-08-101
000E	Ignition Timing Advance (#1)	1/2	Degrees before TDC	UNM-08-72
000F	Intake Air Temperature	1	Degrees Centigrade	UNM-08-102
0010	Air Flow Rate from MAF	1/100	grams/sec	UNM-16-11
0011	Absolute Throttle #1 Position	100/255	% Full Throttle	UNM-08-61
0012	Commanded Secondary Air	-	Bit Mapped	BMP-08-5
0013	Oxygen Sensor Location	-	Bit Mapped	BMP-08-6
0014	Oxygen Sensor - BANK 1 - Sensor 1	-	Packeted	PKT-16-3
0015	Oxygen Sensor - BANK 1 - Sensor 2	-	Packeted	PKT-16-3
0016	Oxygen Sensor - BANK 1 - Sensor 3	-	Packeted	PKT-16-3
0017	Oxygen Sensor - BANK 1 - Sensor 4	-	Packeted	PKT-16-3
0018	Oxygen Sensor - BANK 2 - Sensor 1	-	Packeted	PKT-16-3
0019	Oxygen Sensor - BANK 2 - Sensor 2	-	Packeted	PKT-16-3
001A	Oxygen Sensor - BANK 2 - Sensor 3	-	Packeted	PKT-16-3
001B	Oxygen Sensor - BANK 2 - Sensor 4	-	Packeted	PKT-16-3
001C	Reserved SAE	-	-	-
001D	Reserved SAE	-	-	-
001E	Reserved SAE	-	-	-
001F	Reserved SAE	-	-	-
0020	PIDs Supported (21h - 40h)	-	Bit Mapped	BMP-32-2
0021-003F	Reserved SAE	-	-	-
0040	PIDs Supported (41h - 60h)	-	Bit Mapped	BMP-32-3
0041-00FF	Reserved SAE	-	-	-

OMEGA EXHIBIT 2037

TABLE 5—ENGINE PRN ASSIGNMENTS
(PRNs 1000 - 10FF)

PRN	PARAMETER NAME	RESOLUTION (1 Bit =)	UNITS OF MEASURE	SLOT # (F-N-#)
1000	MIL Status	-	Bit Mapped	BMP-01-1
1001	Number of Emissions Related DTCs	1	Quantity	UNM-07-1
1002	Continuous Evaluation Supported	-	Bit Mapped	BMP-08-1
1003	Trip Evaluation Supported	-	Bit Mapped	BMP-08-2
1004	Trip Evaluation Complete	-	Bit Mapped	BMP-08-3
1005	Sub-System Category of DTC	-	State Encoded	SED-02-1
1006	Most Significant Digit of DTC	-	State Encoded	SED-02-2
1007	Lower 3 Digits of DTC	-	BCD	BCD-12-1
1008	Fuel System Status - Bank 1	-	Bit Mapped	BMP-08-4
1009	Fuel System Status - Bank 2	-	Bit Mapped	BMP-08-4
100A	Oxygen Sensor Voltage	1/200	volts	UNM-08-11
100B	Short Term Fuel Trim	100/128	% Enrichment	UNM-08-92
100D	Most Significant Digit of VIN Number	-	ASCII	ASC-08-01
100E	A/C Clutch Load	25	Watts	UNM-08-165
1015	Injector On Time	2048	microseconds	UNM-08-231
1019	Crankshaft Torque - Absolute	4	N.m Torque	UNM-08-141
1020	Crankshaft Torque - Percent	100/255	% Maximum Torque	UNM-08-61
1021	Engine Boost	100/255	% Full Boost	UNM-08-61
1022	Engine RPM - Low Resolution	32	RPM	UNM-08-171
1023	Engine Idle RPM	16	RPM	UNM-08-161
1024	Engine Revolutions	2	Quantity	UNM-08-121
1025	Barometric Pressure	1	kPaA	UNM-08-101
1026	Engine Coolant Level - Percent	1/2	% Full	UNM-08-71
1027	Engine Coolant Level - Volume	1/10	liters	UNM-08-41
1028	Engine Coolant Capacity	1/10	liters	UNM-08-41
1029	Engine Coolant Pressure	4	kPaG	UNM-08-141
102A	Engine Coolant Fan #1 Speed	100/255	% Full On	UNM-08-61
102B	Engine Oil Temperature	1	Degrees Centigrade	UNM-08-102
102C	Engine Oil Level - Percent	1/2	% Full	UNM-08-71
102D	Engine Oil Level - Volume	1/10	liters	UNM-08-41
102E	Engine Oil Capacity	1/10	liters	UNM-08-41
102F	Engine Oil Pressure	4	kPaG	UNM-08-141
1030	Engine Oil Remaining Life	100/255	% Remaining Life	UNM-08-61
1031	Hydraulic Fan Speed	100/255	% Full On	UNM-08-61
1032	Methanol Content	100/255	% Methanol	UNM-08-61
1033	Maximum Crankshaft Torque	4	N.m Torque	UNM-08-141
1034	Accelerator Pedal Position	100/255	% Pressed Down	UNM-08-61
1035	Absolute Throttle #2 Position	100/255	% Full Throttle	UNM-08-61
1036	Absolute Throttle #3 Position	100/255	% Full Throttle	UNM-08-61
1037	Bank #1 - Converter #1 Temperature	8	Degrees Centigrade	UNM-08-151
1038	Bank #1 - Converter #2 Temperature	8	Degrees Centigrade	UNM-08-151
1039	Bank #2 - Converter #1 Temperature	8	Degrees Centigrade	UNM-08-151
103A	Bank #2 - Converter #2 Temperature	8	Degrees Centigrade	UNM-08-151
103B	Engine Coolant #2 Fan Speed	100/255	% Full On	UNM-08-61
103C	Engine Coolant Temperature - Low Range	1	Degrees Centigrade	UNM-08-104
103D	Engine Coolant Remaining Life	100/255	% Remaining Life	UNM-08-61
103F	Engine Oil Viscosity	1/10	Centistokes (cSt)	UNM-08-41
1040	Number of Engine Cylinders	1	Quantity	UNM-08-101
1041	Number of Valves per Cylinder	1	Quantity	UNM-08-101
1043	Engine Displacement	1/10	liters	UNM-08-41
1044	Fuel Temperature	1	Degrees Centigrade	UNM-08-102
1047	Ignition Switch Position	-	State Encoded	SED-08-5
1048	Engine Redline - Low Resolution	32	RPM	UNM-08-171
1049	Engine Redline - High Resolution	1/4	RPM	UNM-16-31

TABLE 6—TRANSMISSION PRN ASSIGNMENTS
(PRNs 1800 - 18FF)

PRN	Parameter Name	Resolution (1 Bit =)	Units Of Measure	Slot # (F-N-#)
1801	Transmission Fluid Level - Percent	1/2	% Full	UNM-08-71
1802	Transmission Fluid Level - Volume	1/10	liters	UNM-08-41
1803	Transmission Fluid Capacity	1/10	liters	UNM-08-41
1804	Transmission Oil Life	100/255	% Remaining Life	UNM-08-61
1805	Transmission Gear & Lockup Status	-	Packeted	PKT-08-1
1806	Transmission Range Actual (PRNDL)	-	State Encoded	SED-08-4
1807	Transmission Lockup Status	-	State Encoded	SED-02-3
1808	Transmission Actual Gear	-	State Encoded	SED-06-1
1809	Transmission Range Selected (PRNDL)	-	State Encoded	SED-08-4
180A	Transmission Transfer Case (4WD)	-	State Encoded	SED-08-6
180B	Transmission Fluid Temperature	1	Degrees Centigrade	UNM-08-102
180C	Transmission Fluid Pressure	8	kPaG	UNM-08-151
180D	Transmission Commanded Gear	-	State Encoded	SED-08-4
180E	Transmission Actual Gear	-	State Encoded	SED-08-4

TABLE 7—BRAKES/TIRES/WHEELS PRN ASSIGNMENTS
(PRNs 2800 - 28FF)

PRN	Parameter Name	Resolution (1 Bit =)	Units Of Measure	Slot # (F-N-#)
2801	Wheel Speed - Low Resolution	1	km/h	UNM-08-101
2802	Wheel Speed - High Resolution	1/128	km/h	UNM-16-5
2809	Wheel Slip	1/255	Dimensionless	UNM-08-6
2819	Hydraulic Brake Fluid Supply Pump Pressure	32	kPaG	UNM-08-171
281A	Hydraulic Brake Fluid Temperature	1	Degrees Centigrade	UNM-08-102
281B	Hydraulic Brake Fluid Recirculation Pump Pressure	1	kPaG	UNM-08-101
2821	Wheel Rate		SAE Reserved	SAE Reserved
2829	Wheel Angular Velocity		SAE Reserved	SAE Reserved
2831	Wheel Angular Acceleration		SAE Reserved	SAE Reserved
2839	Wheel Load	100/255	% Full Load	UNM-08-61
2841	Brake Fluid Level - Percent	1/2	% Full	UNM-08-71
2842	Brake Fluid Level - Volume	1/100	liters	UNM-08-15
2843	Brake Fluid Remaining Life	100/255	% Remaining Life	UNM-08-61
2844	Brake Fluid Capacity	1/100	liters	UNM-08-15
2849	Tire Temperature	1	Degrees Centigrade	UNM-08-102
2851	Tire Pressure	4	kPaG	UNM-08-141
2859	Tire Type		SAE Reserved	SAE Reserved
2861	Tire Tread Wear Level	100/255	% tread remaining	UNM-08-61

TABLE 8—STEERING PRN ASSIGNMENTS
(PRNs 3000 - 30FF)

PRN	Parameter Name	Resolution (1 Bit =)	Units Of Measure	Slot # (F-N-#)
3001	Steering Wheel Angle	6	Degrees CW from center	SNM-08-61
3005	Power Steering Fluid Temperature	1	Degrees Centigrade	UNM-08-102
3006	Power Steering Fluid Pressure	100	kPaG	UNM-08-185
3007	Power Steering Fluid Level - Percent	1/2	% Full	UNM-08-71
3008	Power Steering Fluid Level - Volume	1/100	liters	UNM-08-15
3009	Power Steering Fluid Remaining Life	100/255	% Remaining Life	UNM-08-61
300B	Power Steering Fluid Capacity	1/100	liters	UNM-08-15
300C	Steering Wheel Rate	1	RPM	UNM-08-101
300D	Steering Wheel Torque	1	N.m Torque	UNM-08-101
300E	Wheel Steer Angle	1/2	Degrees CW from Center	SNM-08-11

TABLE 9—SUSPENSION PRN ASSIGNMENTS
(PRNs 3800 - 38FF)

PRN	Parameter Name	Resolution (1 Bit =)	Units Of Measure	Slot # (F-N-#)
3801	Lateral Acceleration		SAE Reserved	SAE Reserved
3802	Longitudinal Acceleration		SAE Reserved	SAE Reserved
3803	Yaw Acceleration		SAE Reserved	SAE Reserved
3804	Suspension Ride Setting	100/255	% Stiff Setting	UNM-08-61
3805	Suspension Fluid Temperature	1	Degrees Centigrade	UNM-08-102
3806	Suspension Fluid Pressure	100	kPaG	UNM-08-185
3807	Suspension Fluid Level - Percent	1/2	% Full	UNM-08-71
3808	Suspension Fluid Level - Volume	1/32	liters	UNM-08-26
3809	Suspension Fluid Remaining Life	100/255	% Remaining Life	UNM-08-61
380A	Suspension Fluid Capacity	1/32	liters	UNM-08-26
380B	Vehicle Lateral Velocity		SAE Reserved	SAE Reserved
380C	Vehicle Longitudinal Velocity		SAE Reserved	SAE Reserved
380D	Vehicle Yaw Velocity		SAE Reserved	SAE Reserved

TABLE 10—RESTRAINTS PRN ASSIGNMENTS
(PRNs 5800 - 58FF)

PRN	Parameter Name	Resolution (1 Bit =)	Units Of Measure	Slot # (F-N-#)
5801	Shoulder Belt Position	1	Unscaled A/D Counts	UNM-08-101

TABLE 11—DRIVER INFORMATION PRN ASSIGNMENTS
(PRNs 6000 - 60FF)

PRN	Parameter Name	Resolution (1 Bit =)	Units Of Measure	Slot # (F-N-#)
6001	Vehicle Speed - High Resolution - Metric	1/128	km/h	UNM-16-5
6002	Vehicle Speed - High Resolution - English	1/128	mph	UNM-16-5
6003	Compass Direction	3/2	Degrees CW from North	SNM-08-51
6004	Odometer - Vehicle - Metric	1/64	kilometers	UNM-32-31
6005	Fuel Level - Percent	100/255	% Full	UNM-08-61
6006	Fuel Level - Volume	1/100	liters	UNM-16-11
6007	Fuel Capacity	1/100	liters	UNM-16-11
600A	Battery Voltage - Low Resolution	1/16	volts	UNM-08-32
600B	Battery Temperature	1	Degrees Centigrade	UNM-08-102
600C	Electrical Energy Load	1	amps	UNM-08-101
600D	Date (Dw_8:DD:MM:YY)	-	Packeted	PKT-32-3
600E	Year (YY)	-	BCD	BCD-08-1
600F	Year (Yr)	1	year	UNM-08-103
6010	Month (Mn)	-	State Encoded	SED-04-2
6011	Month (MM)	-	BCD	BCD-08-1
6012	Day of Week (Dw_4)	-	State Encoded	SED-04-1
6013	Day of Week (Dw_8)	-	State Encoded	SED-08-2
6014	Day of Month (Dm)	-	State Encoded	SED-08-3
6015	Day of Month (DD)	-	BCD	BCD-08-1
6016	Time of Day (HH:MM:SS)	-	Packeted	PKT-24-1
6017	Hours (HH)	-	BCD	BCD-08-1
6018	Minutes (MM)	-	BCD	BCD-08-1
6019	Seconds (SS)	-	BCD	BCD-08-1
601A	Battery Voltage - High Resolution	1/128	volts	UNM-16-5
601B	Distance Traveled - English	1/8000	miles	UNM-08-1
601C	Fuel Used - Metric	1/64	liters	UNM-16-8
601D	Distance To Empty - English	1/10	miles	UNM-16-21
601E	Vehicle Speed - Low Resolution - English	1	MPH	UNM-08-101
601F	Hours (Hr) - 0 to 23 numeric	1	hour	UNM-08-101
6020	Average Fuel Economy - Low Resolution - Metric	1	liters/100 kilometers	UNM-08-101
6021	Average Fuel Economy - Low Resolution - English	1	MPG	UNM-08-101
6022	Elapsed Time - Seconds	1	Seconds	UNM-08-101
6023	Date (Dw_4\Mn:Dm)	-	Packeted	PKT-16-6

Continued

TABLE 11—DRIVER INFORMATION PRN ASSIGNMENTS (PRNs 6000 - 60FF) (CONTINUED)

PRN	Parameter Name	Resolution (1 Bit =)	Units Of Measure	Slot # (F-N-#)
6024	Elapsed Time - Minutes	1	Minutes	UNM-08-101
6025	Accumulated Ignition On Time	-	Packeted	PKT-24-2
6026	Fuel Used - English	1/64	gallons	UNM-16-8
6027	Distance To Empty - Metric	1/10	kilometers	UNM-16-21
6028	Average Fuel Economy - High Resolution - Metric	1/10	liters/100 kilometersUNM-16-21	
6029	Average Fuel Economy - High Resolution - English	1/10	MPG	UNM-16-21
602A	Elapsed Time - Hours	1	Hours	UNM-08-101
602B	Display Brightness	100/255	% Full On	UNM-08-61
602C	Ignition Off Duration	1	Minutes	UNM-08-101
602D	Outside Air Temperature - High Resolution	1/256	Degrees CentigradeUNM-16-3	
602E	Outside Air Temperature Display	1/2	Degrees Centigrade	UNM-08-73
602F	Minutes (Mn) 0 - 59 numeric	1	minute	UNM-08-101
6030	Time (Hr:Mn)	-	Packeted	PKT-16-5
6031	Odometer - Vehicle - High Resolution - English	1/8000	miles	UNM-32-11
6032	Odometer - Trip - High Resolution - English	128/8000	miles	UNM-24-21
6033	Odometer - Vehicle - Low Resolution - English	1/10	miles	UNM-24-11
6034	Odometer - Trip - Low Resolution - English	1/10	miles	UNM-16-21
6035	Charging Voltage - Low Resolution	1/16	volts	UNM-08-32
6036	Charging Voltage - High Resolution	1/128	volts	UNM-16-5
6037	Charging Current	1	amps	UNM-08-101
6038	Battery Current	1	amps	SNM-08-21
6039	Odometer - Trip - Metric	1/64	kilometers	UNM-24-41
603A	Instantaneous Fuel Economy - Low Resolution - Metric	1	liters/100 kilometers	UNM-08-101
603B	Fuel Used - Percent	100/255	% Used	UNM-08-61
603C	Fuel Used - Volume	1/100	liters	UNM-16-11
603D	Audible Signal Volume	100/255	% Full Volume	UNM-08-61
603E	Audible Signal Type		SAE Reserved	SAE Reserved
603F	Instantaneous Fuel Economy - High Resolution - Metric	1/10	liters/100 kilometers	UNM-16-21
6040	Instantaneous Fuel Economy - Low Resolution - English	1	MPG	UNM-08-101
6041	Instantaneous Fuel Economy - High Resolution - English	1/10	MPGUNM-16-21	
6042	Seconds (Sc) 0 - 59 numeric	1	seconds	UNM-08-101
6047	Alarm Time (HH:MM:SS)	-	Packeted	PKT-24-1
6049	Elapsed Years	1	years	UNM-08-101
604A	Elapsed Months	1	months	UNM-08-101
604B	Elapsed Days	1	days	UNM-08-101

TABLE 12—LIGHTING PRN ASSIGNMENTS (PRNs 7000 - 70FF)

PRN	Parameter Name	Resolution (1 Bit =)	Units Of Measure	Slot # (F-N-#)

TABLE 13—AUDIO PRN ASSIGNMENTS (PRNs 8000 - 80FF)

PRN	Parameter Name	Resolution (1 Bit =)	Units Of Measure	Slot # (F-N-#)

TABLE 14—PERSONAL COMMUNICATION PRN ASSIGNMENTS (PRNs 9000 - 90FF)

PRN	Parameter Name	Resolution (1 Bit =)	Units Of Measure	Slot # (F-N-#)

TABLE 15—HVAC PRN ASSIGNMENTS
(PRNs 9800 - 98FF)

PRN	Parameter Name	Resolution (1 Bit =)	Units Of Measure	Slot # (F-N-#)
9801	HVAC Fan Speed	100/255	% Full On	UNM-08-61
9803	HVAC Door Position	100/255	% Open	UNM-08-61
9804	Electric Defrost Temperature	1	Degrees Centigrade	UNM-08-102
9808	HVAC High-Side Fluid Temperature	1	Degrees Centigrade	UNM-08-102
9809	HVAC Low-Side Fluid Temperature	1	Degrees Centigrade	UNM-08-102
980A	HVAC Low-Side Pressure	5/2	kPaG	UNM-08-125
980B	HVAC Fluid Charge - % Full Charge	100/255	% Full	UNM-08-61
980C	HVAC Fluid Charge - Absolute Weight	10	grams	UNM-08-155
980D	HVAC Fluid Charge Remaining Life	100/255	% Remaining Life	UNM-08-61
980E	HVAC Fluid Charge Capacity	10	grams	UNM-08-155
9810	HVAC Intake Temperature	1/2	Degrees Centigrade	UNM-08-73
9813	HVAC High-Side Pressure	14	kPaG	UNM-08-159
9815	Interior Humidity Level	100/255	% Relative Humidity	UNM-08-61
9816	Interior Air Filter Remaining Life	100/255	% Remaining Life	UNM-08-61
9817	Heat Load Sensor	1/2	mW/cm2	UNM-08-71
9820	Interior Set Temperature	1/2	Degrees Centigrade	UNM-08-73
9830	HVAC Zone Temperature	1/2	Degrees Centigrade	UNM-08-73

TABLE 16—CONVENIENCE PRN ASSIGNMENTS
(PRNs A000 - A0FF)

PRN	Parameter Name	Resolution (1 Bit =)	Units Of Measure	Slot # (F-N-#)
A001	Seat Temperature	1/2	Degrees Centigrade	UNM-08-73
A003	Wiper Mode	-	State Encoded	SED-08-1
A004	Wiper Delay	1/4	seconds	UNM-08-51
A006	Washer Fluid Temperature	1	Degrees Centigrade	UNM-08-102
A007	Washer Fluid Pressure	4	kPaG	UNM-08-141
A008	Washer Fluid Level - Percent	100/255	% Full	UNM-08-61
A009	Washer Fluid Level - Volume	1/10	liters	UNM-08-41
A00A	Washer Fluid Capacity	1/10	liters	UNM-08-41
A00C	Mirror Dimming Level	100/255	% Full Dim	UNM-08-61
A00D	Mirror Horizontal Position	1	Unscaled A/D Counts	UNM-08-101
A00E	Mirror Vertical Position	1	Unscaled A/D Counts	UNM-08-101
A00F	Window Position	1	Unscaled A/D Counts	UNM-08-101
A010	Door Lock Cylinder State	-	State Encoded	SED-08-7
A011	Steering Column Horizontal Position	1	Unscaled A/D Counts	UNM-08-101
A012	Steering Column Vertical Position	1	Unscaled A/D Counts	UNM-08-101
A014	Autolamp Off Delay Time	1	Seconds	UNM-08-101
A015	Vehicle Speed Setting - Low Resolution - Metric	1	km/h	UNM-08-101
A016	Vehicle Speed Setting - High Resolution - Metric	1/128	km/h	UNM-16-5
A017	Vehicle Speed Setting - Low Resolution - English	1	MPH	UNM-08-101
A018	Vehicle Speed Setting - High Resolution - English	1/128	MPH	UNM-16-5

TABLE 17—SECURITY PRN ASSIGNMENTS
(PRNs C000 - C0FF)

PRN	Parameter Name	Resolution (1 Bit =)	Units Of Measure	Slot # (F-N-#)
C001	Remote Transmitter ID	1	ID Number	UNM-08-101

TABLE 18—CONFIGURATION CODES PRN ASSIGNMENTS
(PRNs E000 - E0FF)

PRN	Parameter Name	Resolution (1 Bit =)	Units Of Measure	Slot # (F-N-#)
E021	Vehicle Id Number (VIN) #1	-	VIN character 1	PKT-32-2
E022	Vehicle Id Number (VIN) #2	-	VIN characters 2 - 5	ASC-32-1
E023	Vehicle Id Number (VIN) #3	-	VIN characters 6 - 9	ASC-32-1
E024	Vehicle Id Number (VIN) #4	-	VIN characters 10 - 13	ASC-32-1
E025	Vehicle Id Number (VIN) #5	-	VIN characters 14 - 17	ASC-32-1
E026	Vehicle Id Number (VIN) #6 (reserved for future use)	-	Reserved - SAE	Reserved - SAE
E027	Vehicle Id Number (VIN) #7 (reserved for future use)	-	Reserved - SAE	Reserved - SAE

TABLE 19—TESTER/DIAGNOSTICS PRN ASSIGNMENTS
(PRNs F000 - F0FF)

PRN	Parameter Name	Resolution (1 Bit =)	Units Of Measure	Slot # (F-N-#)

TABLE 20—MISCELLANEOUS PRN ASSIGNMENTS
(PRNs F800 - F8FF)

PRN	Parameter Name	Resolution (1 Bit =)	Units Of Measure	Slot # (F-N-#)
F801	One Byte Zero Fill	0	Zero	UNM-08-0
F802	Two Byte Zero Fill	0	Zero	UNM-16-0
F803	Three Byte Zero Fill	0	Zero	UNM-24-0
F804	Four Byte Zero Fill	0	Zero	UNM-32-0
F805	Five Byte Zero Fill	0	Zero	UNM-40-0
F806	Six Byte Zero Fill	0	Zero	UNM-48-0
F807	Seven Byte Zero Fill	0	Zero	UNM-56-0

7. Scaling, Limit, Offset, and Transfer Function (SLOT) Definitions—This section defines the parameter scaling, limit(s), offset value, and transfer function for bit, byte, or larger variables. These SLOT definitions have been grouped together to avoid duplication in this document and to offer a common list of definitions for use in assigning new parameter definitions. The wide range of these definitions are expected to cover a large number of applications, and should be used for most new definitions as well. Each of these definitions has been assigned a SLOT number for reference purposes but are formatted to include a three-letter mnemonic representing the format, the parameter length in bits, followed by a random sequence number.

The transfer function is shown in two forms to allow use in implementing messages in modules and in interpreting messages found on a network. The two forms are identical but are solved for each of the two variables. The transfer function defines the relationship between computer units (N) in decimal, and engineering units (E) of the data.

The format of the SLOT, identified by the three-letter mnemonic, indicates the category of bit representation. These formats include:

- Multiple Parameter Packeted	PKT
- Bit Mapped with Mask	BMM
- Bit Mapped without Mask	BMP
- Unsigned Numeric	UNM
- 2's Complement Signed Numeric	SNM
- State Encoded	SED
- ASCII Encoded	ASC
- Binary Coded Decimal (BCD)	BCD
- Signed Floating Point (Scientific Notation)	SFP

These formats for each are described in the following paragraphs.

7.1 Multiple Parameter Packeted (PKT) SLOTs—The multiple parameter packet is used to define PRNs which refer to more than one parameter as a group that are related. By grouping multiple parameters, the network bandwidth can be improved, if the groupings are done such that the individual parameters need to be associated such that the each need to be transmitted together. These packets are defined as a sequence of other PRN numbers, in the order that they appear in the message (MSB first). In some cases, a PRN may be assigned to fill bits or bytes with zeros. Each zero fill PRN is an unsigned numeric SLOT with zero as the sequence number.

7.1.1 MULTIPLE PARAMETER PACKETED ASSIGNMENTS

PKT-08-1 Transmission Gear & Lockup Status (PRN 1805)

MSB	PRN 1807	Transmission Lockup Status	2 bits
LSB	PRN 1808	Transmission Gear Engaged	6 bits

PKT-16-1 Trouble Code That Caused Freeze Frame Storage (PRN 0002)

MSB	PRN 1005	Sub-System Category	2 bits
	PRN 1006	MSB of Trouble Code	2 bits
LSB	PRN 1007	Lower Bytes of Trouble Code - BCD	12 bits

PKT-16-2 Fuel System Status (PRN 0003)

MSB	PRN 1008	Fuel System Status - Bank 1	8 bits
LSB	PRN 1009	Fuel System Status - Bank 2	8 bits

PKT-16-3 Oxygen BANK 1, 2 - Sensor 1, 2, 3, or 4 (PRN 0014 - 001B)

MSB	PRN 100A	Oxygen Sensor Voltage	8 bits
LSB	PRN 100B	Short Term Fuel Trim	8 bits

PKT-16-5 Time (Hr:Mn) (PRN 6030)

MSB	PRN 601F	Hours (0 - 23)	8 bits
LSB	PRN 602F	Minutes (0 - 59)	8 bits

PKT-16-6 Date (Dw_4/Mn:Dm) (PRN 6023)

MSB	PRN 6012	Day of Week (1 - 7)	4 bits
	PRN 6010	Month (1 - 12)	4 bits
LSB	PRN 6014	Day of Month (1 - 31)	8 bits

PKT-24-1	Time of Day (HH:MM:SS) (PRN 6016)			
	MSB	PRN 6017	Hours (HH) - BCD	8 bits
		PRN 6018	Minutes (MM) - BCD	8 bits
	LSB	PRN 6019	Seconds (SS) - BCD	8 bits
PKT-24-2	Accumulated Ignition On Time (PRN 6025)			
	MSB	PRN 602A	Elapsed Time-Hours (0-99)	8 bits
		PRN 6024	Elapsed Time-Minutes (0-59)	8 bits
	LSB	PRN 6022	Elapsed Time-Seconds (0-59)	8 bits
PKT-32-1	Number of Emission-Related Trouble Codes & MIL Status (PRN 0001)			
	MSB	PRN 1000	MIL Status	1 bit
		PRN 1001	Number of Emission-Related Trouble Codes	7 bits
		PRN 1002	Continuous Evaluation Supported	8 bits
		PRN 1003	Trip Evaluation Supported	8 bits
	LSB	PRN 1004	Trip Evaluation Complete	8 bits
PKT-32-2	Vehicle Id Number (VIN) #1 (PRN 0021)			
	MSB	PRN F803	Three Byte - Zero Fill	24 bits
	LSB	PRN 100D	MSB of VIN Number	8 bits
PKT-32-3	Date (Dw_8:DD:MM:YY) (PRN 600D)			
	MSB	PRN 6013	Day of Week (1 - 7)	8 bits
		PRN 6015	Day of Month (DD) - BCD	8 bits
		PRN 6011	Month (MM) - BCD	8 bits
	LSB	PRN 600E	Year (YY) - BCD	8 bits

7.2 Bit Mapped Without Mask (BMP) SLOTs—Bit mapped (BMP) SLOTs are used to encode data that typically contains several binary parameters, such as status bits or flags, grouped into a single byte or several bytes. Bit mapped SLOTs can also be used for discrete output control such as warning lamps where each bit would indicate the state of a particular lamp. The data in these bit mapped SLOTs is not followed by a MASK byte. There can be up to 4 bytes of data without a mask.

7.2.1 BIT MAPPED WITHOUT MASK PARAMETER ASSIGNMENTS

BMP-01-1 MIL Status (PRN 1000)

Length:	1 bit	0	1
Item 1:	Malfunction Indicator Lamp (MIL)	Not Commanded On	Commanded On

BMP-08-1 Continuous Evaluation Supported (PRN 1002)

Length:	8 bits	0	1
Item 1:	Not Used		
Item 2:	Not Used		
Item 3:	Not Used		
Item 4:	Not Used		
Item 5:	Not Used		
Item 6:	Comprehensive Component Monitoring	Not Supported	Supported
Item 7:	Fuel System Monitoring	Not Supported	Supported
Item 8:	Misfire Monitoring	Not Supported	Supported

BMP-08-2 Trip Evaluation Supported (PRN 1002)

Length:	8 bits	0	1
Item 1:	EGR System	Not Supported	Supported
Item 2:	Oxygen Sensor Heater	Not Supported	Supported
Item 3:	Oxygen Sensor	Not Supported	Supported
Item 4:	A/C System Refrigerant	Not Supported	Supported
Item 5:	Secondary Air System	Not Supported	Supported
Item 6:	Evaporative Purge System	Not Supported	Supported
Item 7:	Heated Catalyst	Not Supported	Supported
Item 8:	Catalyst	NotSupported	Supported

BMP-08-3 Trip Evaluation Complete (PRN 1004)

		0	1
Length:	8 bits		
Item 1:	EGR System	Test Complete	Test Not Complete
Item 2:	Oxygen Sensor Heater	Test Complete	Test Not Complete
Item 3:	Oxygen Sensor	Test Complete	Test Not Complete
Item 4:	A/C System Refrigerant	Test Complete	Test Not Complete
Item 5:	Secondary Air System	Test Complete	Test Not Complete
Item 6:	Evaporative Purge System	Test Complete	Test Not Complete
Item 7:	Heated Catalyst	Test Complete	Test Not Complete
Item 8:	Catalyst	Test Complete	Test Not Complete

BMP-08-4 Fuel System Status (PRN 1008 & 1009)

		0	1
Length:	8 bits		
Item 1:	Reserved		
Item 2:	Reserved		
Item 3:	Reserved		
Item 4:	Closed Loop, Faulty O_2 Sensor	False	True
Item 5:	Open Loop, Detected Fault	False	True
Item 6:	Open Loop, Driving Conditions	False	True
Item 7:	Closed Loop, Using O_2 Sensor	False	True
Item 8:	Open Loop, Not Ready for Closed	False	True

BMP-08-5 Commanded Secondary Air Status (PRN 0012)

		0	1
Length:	8 bits		
Item 1:	Reserved		
Item 2:	Reserved		
Item 3:	Reserved		
Item 4:	Reserved		
Item 5:	Reserved		
Item 6:	Atmosphere/Off	Not Supported	Supported
Item 7:	Downstream - First Catalyst	Not Supported	Supported
Item 8:	Upstream - First Catalyst	Not Supported	Supported

BMP-08-6 O_2 Sensor Location (PRN 0013)

		0	1
Length:	8 bits		
Item 1:	Bank 2 - Sensor 4 (B4 - S2)	Not Present	Present
Item 2:	Bank 2 - Sensor 3 (B4 - S1)	Not Present	Present
Item 3:	Bank 2 - Sensor 2 (B3 - S2)	Not Present	Present
Item 4:	Bank 2 - Sensor 1 (B3 - S1)	Not Present	Present
Item 5:	Bank 1 - Sensor 4 (B2 - S2)	Not Present	Present
Item 6:	Bank 1 - Sensor 3 (B2 - S1)	Not Present	Present
Item 7:	Bank 1 - Sensor 2	Not Present	Present
Item 8:	Bank 1 - Sensor 1	Not Present	Present

BMP-32-1 PIDs Supported 01h - 20h (PRN 0000)

		0	1
Length:	32 bits		
Byte 1:			
Item 1 - 8:	PID 01h - 08h Supported	Not Supported	Supported
Byte 2:			
Item 9 - 16:	PID 09h - 10h Supported	Not Supported	Supported
Byte 3:			
Item 17 - 24:	PID 11h - 18h Supported	Not Supported	Supported
Byte 4:			
Item 25 - 32:	PID 19h - 20h Supported	Not Supported	Supported

BMP-32-2 PIDs Supported 21h - 40h (PRN 0020)

Length:	32 bits	0	1
Byte 1: Item 1 - 8:	Byte 1: PID 21h - 28h Supported	Not Supported	Supported
Byte 2: Item 9 - 16:	Byte 2: PID 29h - 30h Supported	Not Supported	Supported
Byte 3: Item 17 - 24:	Byte 3: PID 31h - 38h Supported	Not Supported	Supported
Byte 4: Item 25 - 32:	Byte 4: PID 39h - 40h Supported	Not Supported	Supported

BMP-32-3 PIDs Supported 41h - 60h (PRN 0040)

Length:	32 bits	0	1
Byte 1: Item 1 - 8:	PID 41h - 48h Supported	Not Supported	Supported
Byte 2: Item 9 - 16:	PID 49h - 50h Supported	Not Supported	Supported
Byte 3: Item 17 - 24:	PID 51h - 58h Supported	Not Supported	Supported
Byte 4: Item 25 - 32:	PID 59h - 60h Supported	Not Supported	Supported

7.3 Bit Mapped With Mask Bytes (BMM) SLOTs—Bit mapped with mask (BMM) SLOTs are used to encode data that typically contains several binary parameters, such as status bits or flags, grouped into a single byte or several bytes. Bit mapped SLOTs can also be used for discrete output control such as warning lamps where each bit would indicate the state of a particular lamp. The data in these bit mapped SLOTs are always followed by a MASK byte which is used to indicate which bits of the data byte are valid. There can be up to 4 bytes of data including the mask bytes. Valid combinations include up to 2 data bytes each with mask.

7.3.1 BIT MAPPED WITH MASK PARAMETER ASSIGNMENTS—None Defined

7.4 Unsigned Numeric (UNM) SLOTs—Unsigned numeric (UNM) SLOTs are used to encode data that is typically associated with information such as temperature, speed, or percent. The SLOT can be 8, 16, 24, ... 56 bits in length (1 to 7 bytes) and may or may not have an offset. Unsigned numeric SLOTs can also be used for sequential data such as month (1 - 12) or day of month (1 - 31). Each SLOT definition contains a field for: resolution per bit; minimum and maximum value; and transfer function. The transfer function defines the relationship between computer units (N) in decimal, and engineering units (E) of the data.

7.4.1 UNSIGNED NUMERIC VARIABLE ASSIGNMENTS—The unsigned numeric variables have been grouped as follows:

- Table 21 - ZEROs SLOT Assignments
- Table 22 - UNM-xx, Short (< 8 Bit) SLOTs
- Table 23 - UNM-08, 8 Bit SLOTs
- Table 24 - UNM-16, 16 Bit SLOTs
- Table 25 - UNM-24, 24 Bit SLOTs
- Table 26 - UNM-32, 32 Bit SLOTs Assignments

TABLE 21—ZEROs SLOT ASSIGNMENTS

Slot #	Description	Length
UNM-01-0	Zero (0)	1 Bit
UNM-02-0	Zero (0)	2 Bits
UNM-03-0	Zero (0)	3 Bits
UNM-04-0	Zero (0)	4 Bits
UNM-05-0	Zero (0)	5 Bits
UNM-06-0	Zero (0)	6 Bits
UNM-07-0	Zero (0)	7 Bits
UNM-08-0	Zero (0)	8 Bits
UNM-16-0	Zero (0)	16 Bits
UNM-24-0	Zero (0)	24 Bits
UNM-32-0	Zero (0)	32 Bits
UNM-40-0	Zero (0)	40 Bits
UNM-48-0	Zero (0)	48 Bits
UNM-56-0	Zero (0)	56 Bits

TABLE 22 - UNM-xx, SHORT (<8 BIT) SLOTs

Slot #	Scaling (Resolution; 1 Bit =)	Minimum Limit	Maximum Limit	Invalid Range	Transfer Function N =	Transfer Function E =	Comment
01-1	1	0	1	-	E	N	
02-1	1	0	3	-	E	N	
03-1	1	0	7	-	E	N	
04-1	1	0	15	-	E	N	
05-1	1	0	31	-	E	N	
06-1	1	0	63	-	E	N	
07-1	1	0	127	-	E	N	

TABLE 23 - UNM-08, 8 BIT SLOTs

Slot #	Scaling (Resolution; 1 Bit =)	Minimum Limit	Maximum Limit	Invalid Range	Transfer Function N =	Tranefer Function E =	Comment
1	1/8000	0	0.031875	-	E * 8000	N / 8000	=0.000125
2	1/4000	0	0.06375	-	E * 4000	N / 4000	=0.00025
3	1/2000	0	0.1275	-	E * 2000	N / 2000	=0.0005
4	1/1000	0	0.255	-	E * 1000	N / 1000	=0.001
5	1/511	0	0.499	-	E * 511	N / 511	=0.001957
6	1/255	0	1	-	E * 255	N / 255	=0.003922
7	1/100	0	+1.27	-	(E+1.28) * 100	(N / 100) -1.28	=0.01 w/ offset
11	1/200	0	1.275	-	E * 200	N / 200	=0.005
15	1/100	0	2.55	-	E * 100	N / 100	=0.01
21	1/64	0	3.98	-	E * 64	N / 64	=0.0156
26	1/32	0	7.989	-	E * 32	N / 32	=0.03125
31	1/25	0	10.2	-	E * 25	N / 25	=0.04
32	1/16	0	15.94	-	E * 16	N / 16	=0.0625
41	1/10	0	25.5	-	E * 10	N / 10	=0.1
51	1/4	0	63.75	-	E * 4	N / 4	=0.25
55	1/3	0	85	-	E * 3	N / 3	=0.333333
61	100/255	0	100	-	E * 2.55	N / 2.55	=0.39215
71	1/2	0	127.5	-	E * 2	N / 2	=0.5
72	1/2	-64	+63.5	-	(E+64) * 2	(N / 2) -64	=0.5 w/ offset
73	1/2	-40	+87.5	-	(E+40) * 2	(N / 2) -40	=0.5 w/ offset
76	2/3	0	170	-	E * 1.5	N / 1.5	=0.666667
77	2/3	0	100	100.3 to 170	E * 1.5	N / 1.5	=0.666667 w/ limits
81	3/4	0	191.25	-	E / 0.75	N * 0.75	=0.75
82	3/4	-90 (00h)	+90 (F0h)	90.75 (F1h - FFh)	(E+90) /0.75	(N*0.75) -90	=0.75 w/ offset
91	100/128	0	199.22	-	E * 1.28	N / 1.28	=0.78125
92	100/128	-100	+99.22	-	(E+100) * 1.28	(N/1.28) -100	=0.78125 w/ Offset
101	1	0	255	-	E	N	=1
102	1	-40	+215	-	E + 40	N - 40	=1 w/ Offset
104	1	-128	+127	-	E + 128	N - 128	=1 w/ Offset
111	3/2	0 (00h)	360 (F0h)	361.5 (F1h - FFh)	E / 1.5	N * 1.5	-
121	2	0	510	-	E / 2	N * 2	-
125	5/2	0	637.5	-	E * 2 / 5	N * 5 / 2	-
131	3	0	765	-	E / 3	N * 3	-
141	4	0	1020	-	E / 4	N * 4	-
151	8	0	2040	-	E / 8	N * 8	-
155	10	0	2550	-	E / 10	N * 10	-
159	14	0	3570	-	E / 14	N * 14	-
161	16	0	4080	-	E / 16	N * 16	-
165	25	0	6375	-	E / 25	N * 25	-
171	32	0	8160	-	E / 32	N * 32	-
181	64	0	16320	-	E / 64	N * 64	-
185	100	0	25500	-	E / 100	N * 100	-
191	128	0	32640	-	E / 128	N * 128	-
201	256	0	65280	-	E / 256	N * 256	-
211	512	0	130560	-	E / 512	N * 512	-
221	1024	0	261120	-	E / 1024	N * 1024	-
231	2048	0	522240	-	E / 2048	N * 2048	-
241	4096	0	1044480	-	E / 4096	N * 4096	-

TABLE 24—UNM-16, 16 BIT SLOTs

Slot #	Scaling (Resolution; 1 Bit =)	Minimum Limit	Maximum Limit	Invalid Range	Transfer Function N =	Transfer Function E =	Comment
2	1/256	0	255.99	-	E * 256	N / 256	=0.003908
3	1/256	-70	185.99	-	(E + 70) * 256	(N / 256) - 70	=0.003906 w/ offset
5	1/128	0	511.99	-	E * 128	N / 128	=0.007813
8	1/64	0	1023.984	-	E * 64	N / 64	=0.015625
11	1/100	0	655.35	-	E * 100	N / 100	=0.01
21	1/10	0	6553.5	-	E * 10	N / 10	=0.1
31	1/4	0	16383.75	-	E * 4	N / 4	=0.25
41	1	0	65535	-	E	N	-

TABLE 25—UNM-24, 24 BIT SLOTs

Slot #	Scaling (Resolution; 1 Bit =)	Minimum Limit	Maximum Limit	Invalid Range	Transfer Function N =	Transfer Function E =	Comment
11	1/10	0	1677721.5	-	E * 10	N / 10	=0.1
21	128/8000	0	268435.44	-	(E/128) * 8000	(N * 128) / 8000	=0.016
31	128/4000	0	536870.88	-	(E/128) * 4000	(N * 128) / 4000	=0.032
41	1/64	0	262143.98	-	E * 64	N / 64	=0.01563

TABLE 26—UNM-32, 32 BIT SLOTs

Slot #	Scaling (Resolution; 1 Bit =)	Minimum Limit	Maximum Limit	Invalid Range	Transfer Function N =	Transfer Function E =	Comment
11	1/8000	0	536870.9	-	E * 8000	N / 8000	=0.000125
21	1/4000	0	1073741.8	-	E * 4000	N / 4000	=0.00025
31	1/64	0	67108864	-	E * 64	N / 64	=0.01563

7.5 2's Complement Signed Numeric (SNM) SLOTs—Signed numeric (SNM) SLOTs are represented in 2's complement notation. If the most significant bit of the number is set (one, 1), then the number is negative and the absolute value of the number is found by taking the 2's complement of the number. The 2's complement is found by inverting each bit of the number and then adding a binary one (1) to the result. For example, the number FFh, which has its most significant bit set, corresponds to -1.

7.5.1 2'S COMPLEMENT SIGNED NUMERIC VARIABLE ASSIGNMENTS—The 2's complement signed numeric variables are grouped as follows:

- Table 27 - SNM-08, 8 Bit SLOTs

TABLE 27—SNM-08, 8 BIT SLOTs

Slot #	Scaling (Resolution; 1 Bit =)	Minimum Limit	Maximum Limit	Invalid Range	Transfer Function N =	Transfer Function E =	Comment
11	1/2	-64	+63.5	-	E * 2	N / 2	=0.5
21	1	-128	+127	-	E	N	-
41	4	-512	+508	-	E / 4	N * 4	-
51	3/2	-192	+190.5	-	E * 2/3	N * 3/2	-
61	6	-768	+762	-	E / 6	N * 6	-

7.6 State Encoded (SED) SLOTs—State encoded (SED) SLOTs are used for data that can take one of several states such as Day of Week or Wiper Mode. Each SLOT definition contains a field for describing each state within the SLOT. There can be between 1 and 8 bits in any given SLOT with n^2 possible states where n is the number of bits in the SLOT.

7.6.1 STATE ENCODED VARIABLE ASSIGNMENTS

SED-02-1 Sub-System Category Reference Letter (PRN 1005)

Length:	2 bits (0 - 3)
0	"P" = Powertrain
1	"C" = Chassis
2	"B" = Body
3	"U" = Undefined

SED-02-2 Most Significant Digit of Trouble Code (PRN 1006)

Length:	2 bits (0 - 3)
0	"0"
1	"1"
2	"2"
3	"3"

SED-02-3 Transmission Lock-up Status (PRN 1807)

Length:	2 bits (0 - 3)
0	Unlock
1	Partial Lock
2	Full Lock
3	Invalid

SED-04-1 Day of the Week (PRN 6012)

Length:	4 bits (0 - F)
0	Unknown
1	Sunday
2	Monday
3	Tuesday
4	Wednesday
5	Thursday
6	Friday
7	Saturday
8 - F	Invalid

SED-04-2 Month (PRN 6010)

Length:	4 bits (0 - F)
0	Unknown
1	January
2	February
3	March
4	April
5	May
6	June
7	July
8	August
9	September
A	October
B	November
C	December

D - F	Invalid

SED-06-1	Transmission Gear Engaged (PRN 1808)
Length:	6 bits (00 - 3F)
00	Neutral
01	Reverse
02	Forward 1
04	Forward 2
08	Forward 3
10	Forward 4
20	Forward 5
Others	Invalid

SED-08-1	Wiper Mode (PRN A003)
Length:	8 bits (00 - FF)
00	Invalid
01	Off
02	Intermittent
03	Low Speed
04	Medium Speed
05	High Speed
06	Pulse
07 - FF	Invalid

SED-08-2	Day of the Week (PRN 6013)
Length:	8 bits (00 - FF)
00	Unknown
01	Sunday
02	Monday
03	Tuesday
04	Wednesday
05	Thursday
06	Friday
07	Saturday
08 - FF	Invalid

SED-08-3	Day of Month (PRN 6014)
Length:	8 bits (00 - FF)
00	Invalid
0I	1st
02	2nd
03	3rd
04	4th
05	5th
06	6th
07	7th
08	8th
09	9th
0A	10th
0B	11th
0C	12th
0D	13th
0E	14th
0F	15th
10	16th
11	17th
12	18th
13	19th
14	20th
15	21th
16	22nd
17	23rd
18	24th
19	25th
1A	26th
1B	27th
1C	28th
1D	29th
1E	30th
1F	31st
20 - FF	Invalid

SED-08-4	Transmission Range (PRN 1806, 1809, 180D, & 180E)
Length:	8 bits (00 - FF)
00	Invalid
01	Reverse
02	Forward 1
04	Forward 2
08	Forward 3
10	Forward 4
20	Forward 5
40	Forward 6/Park
80	Neutral
Others	Invalid

SED-08-5	Ignition Switch Position (PRN 1047)
Length:	8 bits (00 - FF)
00	Invalid
01	ACC
02	OFF/LOCK
04	OFF/UNLOCK
08	RUN
10	START
Others	Invalid

SED-08-6	Transmission Transfer Case (4WD) (PRN 180A)
Length:	8 bits (00 - FF)
00	Invalid
01	Neutral
02	Two Wheel Drive
03	Four Wheel Drive - Low
04	Four Wheel Drive - High
05 - FF	Invalid

SED-08-07	Door Lock Cylinder State (PRN C002)
Length:	8 bits (00 - FF)
00	Key Out
01	Key In Lock Position
02	Key In Unlock Position
03 - FF	Invalid

7.7 ASCII Encoded (ASC) SLOTs—ASCII (ASC) SLOTs are used to encode ASCII data. The least significant 7 bits represent the standard ASCII codes from 0 to 127. The most significant bit is reserved at this time but may be assigned a special function in the future. Several ASCII characters can be included in a single message by placing up to 7 ASCII characters sequentially in the data field. This allows a character string of up to 7 characters to be sent in a single message.

The ASCII character set is included in Table 27.

7.7.1 ASCII ENCODED VARIABLE ASSIGNMENTS

ASC-08-1	One ASCII Character
Length:	8 bits
Byte 1:	One ASCII Character

ASC-16-1	Two ASCII Characters
Length:	16 bits
Byte 1:	Left Most Character
Byte 2:	Right Most Character

ASC-24-1	Three ASCII Characters
Length:	24 bits
Byte 1:	Left Most Character
Byte 2:	Middle Character
Byte 3:	Right Most Character

ASC-32-1	Four ASCII Characters
Length:	32 bits
Byte 1:	Left Most Character
Byte 2:	Middle Left Character
Byte 3:	Middle Right Character
Byte 4:	Right Most Character

ASC-40-1 Five ASCII Characters
Length: 40 bits
Byte 1: Left Most Character
Byte 2: Middle Left Character
Byte 3: Middle Character
Byte 4: Middle Right Character
Byte 5: Right Most Character

ASC-48-1 Six ASCII Characters
Length: 48 bits
Byte 1: Left Most Character
Byte 2: Middle Left Character
Byte 3: Middle Middle Left Character
Byte 4: Middle Middle Right Character
Byte 5: Middle Right Character
Byte 6: Right Most Character

ASC-56-1 Seven ASCII Characters
Length: 56 bits
Byte 1: Left Most Character
Byte 2: Middle Left Character
Byte 3: Middle Middle Left Character
Byte 4: Middle Character
Byte 5: Middle Middle Right Character
Byte 6: Middle Right Character
Byte 7: Right Most Character

7.7.2 ASCII Character Set—The conversion chart, Table 28, can be used to convert from a two-digit (one byte) hexadecimal number to an ASCII character or from an ASCII character to a two-digit hexadecimal number.

TABLE 28—ASCII CONVERSION CHART

Bits 0 to 3 (LSB)	Bits 4 to 6 First Hex Digit (MSB) 0	1	2	3	4	5	6	7
0	NUL	DLE	SP	0	@	P	`	p
1	SOH	DC1	!	1	A	Q	a	q
2	STX	DC2	"	2	B	R	b	r
3	ETX	DC3	#	3	C	S	c	s
4	EOT	DC4	$	4	D	T	d	t
5	ENQ	NAK	%	5	E	U	e	u
6	ACK	SYN	&	6	F	V	f	v
7	BEL	ETB	'	7	G	W	g	w
8	BS	CAN	(	8	H	X	h	x
9	HT	EM	)	9	I	Y	i	y
A	LF	SUB	*	:	J	Z	j	z
B	VT	ESC	+	;	K	[	k	{
C	FF	FS	,	<	L	\	l	|
D	CR	GS	-	=	M	]	m	}
E	SO	RS	.	>	N	^	n	~
F	SI	US	/	?	O	_	o	DEL

7.8 Binary Coded Decimal (BCD) SLOTs—BCD SLOTs are similar to ASCII SLOTs and are used to encode BCD data. The upper nibble is used to represent the most significant digit in a two-digit number and the lower nibble the least significant digit. For example, the data value 38h would represent 38 decimal. Invalid data ranges include any value that has either nibble greater than 9 (i.e., A, B, ..., F in either nibble). Therefore, a valid value can represent a number from 0 to 9. Several BCD numbers can be included in a single message by placing up to 14 BCD digits sequentially in the data field. This allows any number from 0 to 99,999,999,999,999 to be sent in a single message.

7.8.1 Binary Coded Decimal (BCD) Variable Assignments

BCD-04-1 1 digit
Length: 4 bits
Scaling (Resolution): 1 bit = 1 (BCD)
Limit:
Minimum: 0
Maximum:9

BCD-08-1 2 digits
Length: 8 bits
Scaling (Resolution): 1 bit = 1 (BCD)
Limit:
Minimum: 00
Maximum:99

BCD-12-1 3 digits
Length: 12 bits
Scaling (Resolution): 1 bit = 1 (BCD)
Limit:
Minimum: 000
Maximum:999

BCD-16-1 4 digits
Length: 16 bits
Scaling (Resolution): 1 bit = 1 (BCD)
Limit:
Minimum: 0000
Maximum:9999

BCD-20-1 5 digits
Length: 20 bits
Scaling (Resolution): 1 bit = 1 (BCD)
Limit:
Minimum: 00000
Maximum:99999

BCD-24-1 6 digits
Length: 24 bits
Scaling (Resolution): 1 bit = 1 (BCD)
Limit:
Minimum: 000000
Maximum:999999

BCD-28-1 7 digits
Length: 28 bits
Scaling (Resolution): 1 bit = 1 (BCD)
Limit:
Minimum: 0000000
Maximum:9999999

BCD-32-1 8 digits
Length: 32 bits
Scaling (Resolution): 1 bit = 1 (BCD)
Limit:
Minimum: 00000000
Maximum:99999999

BCD-36-1 9 digits
Length: 36 bits
Scaling (Resolution): 1 bit = 1 (BCD)
Limit:
Minimum: 000000000
Maximum:999999999

BCD-40-1 10 digits
Length: 40 bits
Scaling (Resolution): 1 bit = 1 (BCD)
Limit:
Minimum: 0000000000
Maximum:9999999999

BCD-44-1 11 digits
Length: 44 bits
Scaling (Resolution): 1 bit = 1 (BCD)
Limit:
Minimum: 00000000000
Maximum:99999999999

BCD-48-1 12 digits
Length: 48 bits
Scaling (Resolution): 1 bit = 1 (BCD)
Limit:
Minimum: 000000000000
Maximum:999999999999

BCD-52-1 13 digits
Length: 52 bits
Scaling (Resolution): 1 bit = 1 (BCD)
Limit:
Minimum: 0000000000000
Maximum: 9999999999999

BCD-56-1 14 digits
Length: 56 bits
Scaling (Resolution): 1 bit = 1 (BCD)
Limit:
Minimum: 00000000000000
Maximum: 99999999999999

7.9 Signed Floating Point [Scientific Notation] (SFP) SLOT—The Signed Floating Point (SFP) SLOT is used to encode data that needs to be represented in floating point arithmetic, and always includes a leading sign character. The format exactly follows the ANSI/IEEE Standard (Std 754-1985) Single format. Please note that the data byte boundaries of the transmitted frame do not align with the boundaries of this format. The floating point parameter is sent as a 32 bit (4 byte) variable. The bit order is shown in Figure 14.

7.9.1 SIGNED FLOATING POINT VARIABLE ASSIGNMENT

SFP-32-1 Floating Point

	1 bit	8 bits	23 bits	
. . .	Sign Bit	Exponent	Fractional Part	. . .
	MSB		LSB	

FIGURE 14—SIGNED FLOATING POINT (SCIENTIFIC NOTATION) (SFP) SLOT

*8. **Multiple Frame, Single Parameter Format***—This section defines the method of encoding long parameters that require more than one frame to complete. The first data byte for this format is a sequence number as shown in Figure 15. The sequence byte consists of an upper nibble that identifies this frame by number in the sequence. The lower nibble is the total number of frames that make up this grouping. The sequence byte is followed by up to the maximum number of data bytes allowed by SAE J1850, for each frame. The entire parameter is thus built up from the total number of frames shown in the sequence tracking byte, in the order carried in that byte. The data field format will thus have an order indicated by Figure 16.

A simple example of this format is shown in Figures 17, 18, and 19, sending an ASCII string of characters.

	MSB	LSB	
. . .	Frame # (4 bits)	# of Frames (4 bits)	. . .

FIGURE 15—SEQUENCE TRACKING BYTE

. . .	Sequence Byte	Data Byte 1	Data Byte 2	Data Byte 3	. . .

FIGURE 16—MULTIPLE FRAME, SINGLE PARAMETER FIELD

. . .	Sequence 1 of 3	54h T	68h h	65h e	20h SP	51h Q	75h u	69h i	. . .

FIGURE 17—FIRST SEQUENCE FRAME

. . .	Sequence 2 of 3	63h c	6Bh k	20h SP	42h B	72h r	6Fh o	77h w	. . .

FIGURE 18—SECOND SEQUENCE FRAME

. . .	Sequence 3 of 3	6Eh n	20h SP	54h T	72h r	6Fh o	75h u	74h t	. . .

FIGURE 19—LAST SEQUENCE FRAME

SAE The Engineering Society For Advancing Mobility Land Sea Air and Space®
INTERNATIONAL
400 Commonwealth Drive, Warrendale, PA 15096-0001

SURFACE VEHICLE RECOMMENDED PRACTICE

SAE J2178/3

Issued 1993-09-07

Submitted for recognition as an American National Standard

CLASS B DATA COMMUNICATION NETWORK MESSAGES—PART 3 FRAME IDs FOR SINGLE BYTE FORMS OF HEADERS

TABLE OF CONTENTS

1. Scope . . . 2

1.1 Standardized Parameter Definitions . . . 3

2. References . . . 3

2.1 Applicable Documents . . . 3
2.2 Related Publications . . . 3
2.3 Terms and Definitions . . . 3
2.3.1 Data [Data Field] . . . 3
2.3.2 Frame . . . 4
2.3.3 Header [Header Field] . . . 4
2.3.4 In-Frame Response (IFR) Type . . . 4
2.3.5 Message . . . 4
2.3.6 Parameter . . . 4
2.3.7 Priority . . . 4
2.3.8 Response Data . . . 4
2.4 Abbreviations and Acronyms . . . 4

3. General Information . . . 4

3.1 Document Overview . . . 4
3.2 Parameter Reference Number (PRN) . . . 5
3.3 Message Identification (FRAME ID) . . . 5
3.3.1 PRN Assignments . . . 5
3.3.2 In-Frame Response (IFR) Type . . . 5
3.3.3 Repetition Rate . . . 5
3.3.4 CRC Byte Requirements . . . 5

4. Frame IDs for Single Byte Forms of Headers . . . 6

SAE Technical Standards Board Rules provide that: "This report is published by SAE to advance the state of technical and engineering sciences. The use of this report is entirely voluntary, and its applicability and suitability for any particular use, including any patent infringement arising therefrom, is the sole responsibility of the user."

SAE reviews each technical report at least every five years at which time it may be reaffirmed, revised, or cancelled. SAE invites your written comments and suggestions.

Copyright 1993 Society of Automotive Engineers, Inc.
All rights reserved.

Printed in U.S.A.

Page 363 of 1986 OMEGA EXHIBIT 2037

1. *Scope*—This SAE Recommended Practice defines the information contained in the header and data fields of nondiagnostic messages for automotive serial communications based on SAE J1850 Class B networks. This document describes and specifies the header fields, data fields, field sizes, scaling, representations, and data positions used within messages.

The general structure of a SAE J1850 message frame without in-frame response is shown in Figure 1. The structure of a SAE J1850 message with in-frame response is shown in Figure 2. Figures 1 and 2 also show the scope of frame fields defined by this document for nondiagnostic messages. Refer to SAE J1979 for specifications of emissions-related diagnostic message header and data fields. Refer to SAE J2190 for the definition of other diagnostic message header and data fields. The description of the network interface hardware, basic protocol definition, the electrical specifications, and the CRC field are given in SAE J1850.

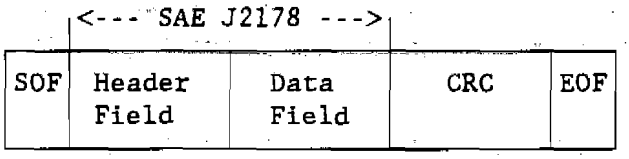


FIGURE 1—SCOPE OF SAE J2178 FOR A SAE J1850 FRAME WITHOUT IN-FRAME RESPONSE

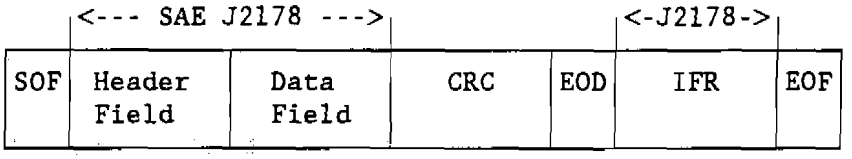


FIGURE 2—SCOPE OF SAE J2178 FOR A SAE J1850 FRAME WITH IN-FRAME RESPONSE (IFR)

SAE J1850 defines two and only two formats of message headers. They are the Single Byte header format and the Consolidated header format. The consolidated header format has two forms: a single byte form and a three byte form. This document covers all of these formats and forms to identify the contents of messages which could be sent on a SAE J1850 network.

This document consists of four parts, each published separately.

Part 1 of SAE J2178 (Titled: Detailed Header Formats and Physical Address Assignments) describes the two allowed forms of message header formats: single byte and consolidated. It also contains the physical node address range assignments for the typical subsystems of an automobile.

Part 2 of SAE J2178 (Titled: Data Parameter Definitions) defines the standard parametric data which may be exchanged on SAE J1850 (Class B) networks. The parameter scaling, ranges, and transfer functions are specified. Messages which refer to these parametric definitions shall always adhere to these parametric definitions. It is intended that at least one of the definitions for each parameter in this part match the SAE J1979 definition. The details of this part are fully described in 3.1.

Part 3 of SAE J2178 (this part, Titled: Frame IDs for Single Byte Forms of Headers) defines the message assignments for the single byte header format and the one byte form of the consolidated header format.

Part 4 of SAE J2178 (Titled: Target Address (Second Byte) for Three Byte Headers) defines the message assignments for the second byte in the three byte form of the consolidated header format.

1.1 **Standardized Parameter Definitions**—The parameters used to describe data variables are one of the most important functions of this document. To achieve commonality of messages in Class B networks, the data parameters must become standardized. This applies to data parameter definitions for use during normal vehicle operations as well as during diagnostic operations. By using common parameter definitions for nondiagnostic and diagnostic functions on the network, the modules which form the network can maintain one image or description of a data parameter.

Where parameters have been defined in the Diagnostic Test Modes documents (SAE J1979 and J2190), such as Parameter Identifiers for diagnostic purposes, the definitions in Part 2 of this document match the diagnostic definition.

SAE J2178, Part 2 defines the parameters to be used for nondiagnostic and diagnostic data format definitions. For new parameter definitions which are needed in the future, the new definitions, if they are expected to become widely used, must be integrated into this document for commonality across these types of applications. Of course, manufacturers are free to assign their own definitions to data parameters which are unique or proprietary to their products. They are, however, restricted to using the "Manufacturer Reserved" message header assignments in Parts 3 and 4 of this document when using these unique or proprietary data parameter definitions.

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.

SAE J1850—Class B Data Communication Network Interface
SAE J1979—E/E Diagnostic Test Modes
SAE J2178/1—Detailed Header Formats and Physical Address Assignments
SAE J2178/2—Data Parameter Definitions
SAE J2178/4—Target Address (Second Byte) for Three Byte Headers (Draft)
SAE J2190—Enhanced E/E Diagnostic Test Modes

2.2 **Related Publications**—The following publications are provided for information purposes only and are not a required part of this document.

SAE J1213/1—Glossary of Vehicle Networks for Multiplex and Data Communication
SAE J1930—Electrical/Electronic Systems Diagnostic Terms, Definitions, Abbreviations, and Acronyms

2.3 Terms and Definitions

2.3.1 DATA [DATA FIELD]—Data and data field are used interchangeably in this document and they both refer to a field within a frame that may include bytes with parameters pertaining to the message and/or secondary ID and/or extended addresses and/or test modes which further defines a particular message content being exchanged over the network.

2.3.2 FRAME—A frame is one complete transmission of information which may or may not include an In-Frame Response. The frame is enclosed by the start of frame and end of frame symbols. For Class B networks, each frame contains one and only one message (see "message" 2.3.5).

2.3.3 HEADER [HEADER FIELD]—The header (or header field, used interchangeably) is a one or three byte field within a frame which contains information about the message priority, message source and target addressing, message type, and in-frame response type.

2.3.4 IN-FRAME RESPONSE (IFR) TYPE—The IFR type identifies the form of the in-frame response which is expected within that message.

2.3.5 MESSAGE—A message consists of all of the bytes of a frame excluding the delimiter symbols (SOF, EOD, EOF, NB).

2.3.6 PARAMETER—A parameter is the variable quantity included in some messages. The parameter value, scaling, offset, units, transfer function, etc., are unique to each particular message. (The assigned parameters are contained herein.)

2.3.7 PRIORITY—The priority describes the rank order and precedence of a message. Based upon the SAE J1850, Class B arbitration process, the message with the highest priority will win arbitration.

2.3.8 RESPONSE DATA—The response data is the information from a node on the network in response to a request from another node on the network. This may be an in-frame response or a report type of message.

2.4 Abbreviations and Acronyms

CRC - Cyclic Redundancy Check
EOD - End of Data
EOF - End of Frame
ID - Identifier
IFR - In-Frame Response
LSB - Least Significant Bit / Byte
MSB - Most Significant Bit / Byte
NB - Normalization Bit
PKT - Multiple Parameter Packet SLOT
PRN - Parameter Reference Number
SLOT - Scaling, Limit, Offset, and Transfer Function
SOF - Start of Frame

3. General Information

3.1 Document Overview—The messages defined by this document are specified for networks using one byte headers or the single byte form of the consolidated header as specified in SAE J1850. This document focuses on the Frame ID which is the first byte of the message. The first byte of the one byte header is defined in Section 4 under Frame ID as an 8 Bit hexadecimal number and the first byte of the single byte form of the consolidated header is defined under 7 Bit as a hexadecimal number. Bit four (H bit) of the 7 Bit header is always a logic "1" (see Section 5 of SAE J2178 Part 1). The information in the header field implicitly defines the target, source, priority and message type information, while the data field contains additional addressing and parametric information (see Section 4 of SAE J2178 Part 1). The header defines the Message Identifier or Frame ID and becomes the name that is broadcast normally periodically to all the nodes on the network.

This document describes the overall structure of messages and is expected to have wide application. Designers are required to use the defined messages on SAE J1850 networks in the exact way that they are defined here. There are a large number of message codes which are reserved for each manufacturer to define. If the user cannot find a needed message, he or she is expected to define a manufacturer-specific message in these reserved codes. Therefore, messages on different manufacturer's products using these "Manufacturer Reserved" codes will only have meaning for that manufacturer or specific vehicle. These will most likely be different between manufacturers. The codes that are defined here, however, shall always carry the same meaning from one manufacturer to another and from one model and year to the next.

3.2 **Parameter Reference Number (PRN)**—With the Single Byte form of header, the Frame ID corresponds with a particular Parameter Reference Number (PRN) or a grouping of PRNs (see Section 6 of SAE J2178 Part 2). The PRN is an arbitrarily assigned number and defines the following:

a. Length of data in number of bits
b. Units
c. Scaling, Limit, Offset, and Transfer Function, i.e., SLOT (see Section 7 of SAE J2178 Part 2)
d. Type or category of data

SAE J2178 Part 2, Section 7 defines the following data Types:

(1) BMP Bit Mapped
(2) UNM Unsigned Numeric
(3) SNM 2's Complement Signed Numeric
(4) SED State Encoded
(5) ASC ASCII Encoded
(6) BCD Binary Coded Decimal
(7) SFP Signed Floating Point (Scientific Notation)

3.3 **Message Identification (FRAME ID)**—The FRAME ID of the single byte header implicitly and uniquely defines the following characteristics of the message:

a. The message priority
b. The data content of the message specified by a PRN or packet of PRNs
c. The length of message
d. Source of the message
e. Type of the message
f. The event or repetition rate for transmission
g. CRC byte requirements

3.3.1 PRN ASSIGNMENTS—A FRAME ID shall have one or more PRNs assigned to it. Some PRNs may be composed of a packet (PKT) of PRNs (see paragraph 7.1 of SAE J2178 Part 2). The bytes of the data field shall be composed of the parameter given in the "PRNs" column of the figure defined in Section 4. When more than one PRN is shown, the data field shall contain the PRNs in the order given left to right.

3.3.2 IN-FRAME RESPONSE (IFR) TYPE—The IFR Type shall be given under "IFR Type" column of the figure defined in Section 4. The different IFR Types are defined in Section 3 of J2178 Part 1.

3.3.3 REPETITION RATE—The vehicle manufacturer shall choose which message frames are event driven or defined by a repetition rate. Refer to SAE J2178 Part 1 Appendix A for further information on event- or time-based message frames.

3.3.4 CRC BYTE REQUIREMENTS—The CRC byte requirements shall be defined by the manufacturer as specified by SAE J1850.

4. ***Frame IDs for Single Byte Forms of Headers***—Figure 3 defines the Frame ID for one byte headers and the first byte of the single byte form of the consolidated header.

FRAME ID				
7 Bit	8 Bit	IFR Type	Function	PRNs
10	00		Reserved - SAE	
	01		Reserved - SAE	
11	02		Reserved - Mfg.	
	03		Reserved - Mfg.	
12	04		Reserved - Mfg.	
	05		Reserved - Mfg.	
13	06		Reserved - Mfg.	
	07		Reserved - Mfg.	
14	08		Reserved - SAE	
	09		Reserved - SAE	
15	0A		Reserved - Mfg.	
	0B		Reserved - Mfg.	
16	0C		Reserved - Mfg.	
	0D		Reserved - Mfg.	
17	0E		Reserved - Mfg.	
	0F		Reserved - Mfg.	
18	10		Reserved - SAE	
	11		Reserved - SAE	
19	12		Reserved - Mfg.	
	13		Reserved - Mfg.	
1A	14		Reserved - Mfg.	
	15		Reserved - Mfg.	
1B	16		Reserved - Mfg.	
	17		Reserved - Mfg.	
1C	18		Reserved - SAE	
	19		Reserved - SAE	
1D	1A		Reserved - Mfg.	
	1B		Reserved - Mfg.	

FIGURE 3—FRAME IDs FOR SINGLE BYTE FORMS OF HEADERS

FRAME ID				
7 Bit	8 Bit	IFR Type	Function	PRNs
1E	1C		Reserved - SAE	
	1D		Reserved - SAE	
1F	1E		Reserved - Mfg.	
	1F		Reserved - Mfg.	
30	20	0	Injector Time & Dist.	1015, 601B
	21		Reserved - SAE	
31	22		Reserved - Mfg.	
	23		Reserved - Mfg.	
32	24	0	Vehicle Speed	601E, 000D
	25		Reserved - Mfg.	
33	26	0	Engine RPM & MAP	1022, 000B
	27		Reserved - Mfg.	
34	28		Reserved - SAE	
	29		Reserved - SAE	
35	2A	0	Barometric Pressure	1025
	2B		Reserved - Mfg.	
36	2C	0	Sys. Volts & Coolant Temperature	600A, 103C
	2D		Reserved - Mfg.	
37	2E		Reserved - Mfg.	
	2F		Reserved - Mfg.	
38	30		Reserved - SAE	
	31		Reserved - SAE	
39	32		Reserved - Mfg.	
	33		Reserved - Mfg.	
3A	34		Reserved - Mfg.	
	35		Reserved - Mfg.	
3B	36		Reserved - Mfg.	

FIGURE 3—FRAME IDs FOR SINGLE BYTE FORMS OF HEADERS (CONTINUED)

FRAME ID				
7 Bit	8 Bit	IFR Type	Function	PRNs
	37		Reserved - Mfg.	
3C	38		Reserved - SAE	
	39		Reserved - SAE	
3D	3A	0	Transmission Gear & Lock-up Status	1805
	3B		Reserved - Mfg.	
3E	3C	0	Throttle Position	0011
	3D		Reserved - Mfg.	
3F	3E		Reserved - Mfg.	
	3F		Reserved - Mfg.	
50	40	0	Transmission Range	1809
	41		Reserved Diagnostic Report	
51	42		Reserved - SAE	
	43		Reserved - SAE	
52	44		Reserved - Mfg.	
	45		Reserved - Mfg.	
53	46		Reserved - Mfg.	
	47		Reserved - Mfg.	
54	48	0	Leg. Diagnostic Report	Per SAE J1979
	49		Reserved - SAE	
55	4A		Reserved - SAE	
	4B		Reserved - SAE	
56	4C		Reserved - Mfg.	
	4D		Reserved - Mfg.	
57	4E		Reserved - Mfg.	
	4F		Reserved - Mfg.	
58	50		Reserved - SAE	
	51		Reserved - SAE	
59	52		Reserved - Mfg.	

FIGURE 3—FRAME IDs FOR SINGLE BYTE FORMS OF HEADERS (CONTINUED)

FRAME ID				
7 Bit	8 Bit	IFR Type	Function	PRNs
	53		Reserved - Mfg.	
5A	54		Reserved - Mfg.	
	55		Reserved - Mfg.	
5B	56		Reserved - Mfg.	
	57		Reserved - Mfg.	
5C	58		Reserved - SAE	
	59		Reserved - SAE	
5D	5A		Reserved - Mfg.	
	5B		Reserved - Mfg.	
5E	5C		Reserved - Mfg.	
	5D		Reserved - Mfg.	
5F	5E	0	Set Time	6030
	5F		Reserved - Mfg.	
70	60	0	Set Date	6023
	61		Reserved Diagnostic Request	
71	62		Reserved - Mfg.	
	63		Reserved - Mfg.	
72	64		Reserved - Mfg.	
	65		Reserved - Mfg.	
73	66		Reserved - SAE	
	67		Reserved - SAE	
74	68	0	Leg. Diagnostic Req.	Per SAE J1979
	69		Reserved - SAE	
75	6A		Reserved - Mfg.	
	6B		Reserved - Mfg.	
76	6C		Reserved - Mfg.	
	6D		Reserved - Mfg.	
77	6E		Reserved - Mfg.	

FIGURE 3—FRAME IDs FOR SINGLE BYTE FORMS OF HEADERS (CONTINUED)

FRAME ID				
7 Bit	8 Bit	IFR Type	Function	PRNs
	6F		Reserved - Mfg.	
78	70		Reserved - SAE	
	71		Reserved - SAE	
79	72	0	Vehicle Odometer	6031
	73		Reserved - Mfg.	
7A	74	0	Trip Odometer 1	6032
	75		Reserved - Mfg.	
7B	76	0	Trip Odometer 2	6032
	77		Reserved - Mfg.	
7C	78	0	Trip Odometer 3	6032
	79		Reserved - SAE	
7D	7A		Reserved - Mfg.	
	7B		Reserved - Mfg.	
7E	7C		Reserved - Mfg.	
	7D		Reserved - Mfg.	
7F	7E	0	Display Brightness Level	602B
	7F		Reserved - Mfg.	
90	80	0	Current Time	6030
	81		Reserved - SAE	
91	82	0	Oil Pressure	102F
	83		Reserved - Mfg.	
92	84		Reserved - SAE	
	85		Reserved - Mfg.	
93	86		Reserved - Mfg.	
	87		Reserved - Mfg.	
94	88		Reserved - Mfg.	
	89		Reserved - SAE	
95	8A		Reserved - SAE	

FIGURE 3—FRAME IDs FOR SINGLE BYTE FORMS OF HEADERS (CONTINUED)

FRAME ID				
7 Bit	8 Bit	IFR Type	Function	PRNs
	8B		Reserved - Mfg	
96	8C		Reserved - Mfg.	
	8D		Reserved - Mfg.	
97	8E		Reserved - Mfg.	
	8F		Reserved - Mfg.	
98	90	0	Fuel Economy, Present	6021, 6020
	91		Reserved - Mfg.	
99	92	0	Current Date	6023
	93		Reserved - Mfg.	
9A	94	0	Ign. Off Time	602C
	95		Reserved - -Mfg.	
9B	96		Reserved - SAE	
	97		Reserved - SAE	
9C	98		Reserved - Mfg.	
	99		Reserved - Mfg.	
9D	9A	0	Accum. Ign. On Time	6025
	9B		Reserved - Mfg.	
9E	9C		Reserved - SAE	
	9D		Reserved - Mfg.	
9F	9E	0	Fuel Consumed	6026
	9F		Reserved - Mfg.	
B0	A0	0	Distance to Empty	6027
	A1		Reserved - SAE	
B1	A2	0	Fuel Economy, Average	6029, 6028
	A3		Reserved - Mfg.	
B2	A4	0	Fuel Tank Level	6005
	A5		Reserved - Mfg.	
B3	A6		Reserved - Mfg.	

FIGURE 3—FRAME IDs FOR SINGLE BYTE FORMS OF HEADERS (CONTINUED)

FRAME ID				
7 Bit	8 Bit	IFR Type	Function	PRNs
	A7		Reserved - Mfg.	
B4	A8		Reserved - SAE	
	A9		Reserved - SAE	
B5	AA		Reserved - Mfg.	
	AB		Reserved - Mfg.	
B6	AC		Reserved - Mfg.	
	AD		Reserved - Mfg.	
B7	AE		Reserved - Mfg.	
	AF		Reserved - Mfg.	
B8	B0		Reserved - Mfg.	
	B1		Reserved - Mfg.	
B9	B2		Reserved - SAE	
	B3		Reserved - SAE	
BA	B4		Reserved - Mfg.	
	B5		Reserved - Mfg.	
BB	B6		Reserved - Mfg.	
	B7		Reserved - Mfg.	
BC	B8		Reserved - Mfg.	
	B9		Reserved - Mfg.	
BD	BA		Reserved - Mfg.	
	BB		Reserved - Mfg.	
BE	BC		Reserved - Mfg.	
	BD		Reserved - Mfg.	
BF	BE		Reserved - Mfg.	
	BF		Reserved - Mfg.	
D0	C0		Reserved - SAE	
	C1		Reserved - SAE	
D1	C2		Reserved - Mfg.	

FIGURE 3—FRAME IDs FOR SINGLE BYTE FORMS OF HEADERS (CONTINUED)

FRAME ID				
7 Bit	8 Bit	IFR Type	Function	PRNs
	C3		Reserved - Mfg.	
D2	C4		Reserved - Mfg.	
	C5		Reserved - Mfg.	
D3	C6		Reserved - Mfg.	
	C7		Reserved - Mfg.	
D4	C8		Reserved - Mfg.	
	C9		Reserved - SAE	
D5	CA		Reserved - SAE	
	CB		Reserved - Mfg.	
D6	CC	0	Outside Temperature	602D
	CD		Reserved - Mfg.	
D7	CE		Reserved - Mfg.	
	CF		Reserved - Mfg.	
D8	D0		Reserved - Mfg.	
	D1		Reserved - Mfg.	
D9	D2		Reserved - Mfg.	
	D3		Reserved - Mfg.	
DA	D4		Reserved - Mfg.	
	D5		Reserved - Mfg.	
DB	D6		Reserved - Mfg.	
	D7		Reserved - Mfg.	
DC	D8		Reserved - SAE	
	D9		Reserved - SAE	
DD	DA		Reserved - Mfg.	
	DB		Reserved - Mfg.	
DE	DC		Reserved - Mfg.	
	DD		Reserved - Mfg.	
DF	DE		Reserved - Mfg.	

FIGURE 3—FRAME IDs FOR SINGLE BYTE FORMS OF HEADERS (CONTINUED)

FRAME ID				
7 Bit	8 Bit	IFR Type	Function	PRNs
	DF		Reserved - Mfg.	
F0	E0		Reserved - Mfg.	
	E1		Reserved - SAE	
F1	E2		Reserved - SAE	
	E3		Reserved - Mfg.	
F2	E4		Reserved - Mfg.	
	E5		Reserved - Mfg.	
F3	E6		Reserved - Mfg.	
	E7		Reserved - Mfg.	
F4	E8		Reserved - Mfg.	
	E9		Reserved - SAE	
F5	EA		Reserved - SAE	
	EB		Reserved - Mfg.	
F6	EC		Reserved - Mfg.	
	ED		Reserved - Mfg.	
F7	EE		Reserved - Mfg.	
	EF		Reserved - Mfg.	
F8	F0		Reserved - Mfg.	
	F1		Reserved - Mfg.	
F9	F2		Reserved - Mfg.	
	F3		Reserved - Mfg.	
FA	F4		Reserved - Mfg.	
	F5		Reserved - Mfg.	
FB	F6		Reserved - SAE	
	F7		Reserved - SAE	
FC	F8		Reserved - Mfg.	
	F9		Reserved - Mfg.	
FD	FA		Reserved - Mfg.	

FIGURE 3—FRAME IDs FOR SINGLE BYTE FORMS OF HEADERS (CONTINUED)

FRAME ID				
7 Bit	8 Bit	IFR Type	Function	PRNs
	FB		Reserved - Mfg.	
FE	FC		Reserved - Mfg.	
	FD		Reserved - Mfg.	
FF	FE		Reserved - Mfg.	
	FF		Reserved - Mfg.	

FIGURE 3—FRAME IDs FOR SINGLE BYTE FORMS OF HEADERS (CONTINUED)

Bibliography of Related SAE Technical Papers

SAE Technical Paper 941054, Beck, Donald D.; Silvis, Thomas W.; Mahan, Stephen T., "Impact of Fuel Sulfur on OBD-II Catalyst Monitoring Using the Dual Oxygen Sensor Approach."

SAE Technical Paper 940975, Ribbens, William B.; Park, Jaehong, "Road Tests of a Misfire Detection System."

SAE Technical Paper 940800, Daon, Q.; Lynn, M.; Steele, R., "Diagnostic Procedures for Passive Optical Star Vehicle Networks."

SAE Technical Paper 940795, Hetzel, Herbert; Scharpp, Harald; Heck, Patrick, "Advanced Entertainment and Communication Networking Based on Fiber Optics for Vehicle Applications."

SAE Technical Paper 940627, Wollschlager, Randall; Wellnitz, Keith M.; Frank, Randy, "Diagnostics and Communications in Vehicle Control Systems Using Smart Power ICs."

SAE Technical Paper 940494, Grohmann, Dieter; Kienzel, Stefan; Bender, Klaus, "A Flexible Reference Model for the Test System Development."

SAE Technical Paper 940432, Gray, Moshe, "Overcoming the Limitations of the System Architecture of On-Board Vehicle Diagnostics."

SAE Technical Paper 940256, Paparo, Mario; Javurek, William; Smith, William H.; Pietrobon, Giovanni, "A Very Low Noise uP, Interfaced, Multiple High Side Driver with Self Diagnostics for Car Radio Application."

SAE Technical Paper 940143, Connolly, Francis T., "Direct Estimation of Cyclic Combustion Pressure Variability Using Engine Speed Fluctuations in an Internal Combustion Engine."

SAE Technical Paper 940137, Beyeler, Bruce; Langley, Todd, "Using the MC68332 TPU to Implement the J1850 Protocol."

SAE Technical Paper 940007, Mazeau, Philippe, "On-Board Maintenance Systems - The Ultimate Solution."

SAE Technical Paper 933069, Munch, Joseph C. Jr., "Evolution of Vehicle Based Monitoring Systems."

SAE Technical Paper 933022, Leverett, Whit, "Trends in Instrumentation."

SAE Technical Paper 933021, Dannenberg, R. D., "Instrument Gauges Designed to Meet the Customer's Needs."

SAE Technical Paper 932966, Haynes, Skip; Banks, Dave; Beauchamp, Mark; Grabowski, Joe; Johnson, Jeff, "Using Proven Advanced Wiring Techniques to Make a Smart Transit Bus an Operational Reality."

SAE Technical Paper 932873, Eastwood, Peter G., "Measurement of Catalytic Converter Performance Using Exhaust Gas Sensors with Modified Characteristics."

SAE Technical Paper 932854, Pelters, Stephan; Schwarzenthal, Dietmar; Maus, Wolfgang; Swars, Helmut; Braxck, Rolf, "Alternative Technologies for Studying Catalyst Behaviour to Meet OBD II Requirements."

SAE Technical Paper 932665, Unger, Anders; Smith, Kent, "The OBD II System in the Volvo 850 Turbo."

SAE Technical Paper 932664, Glidewell, John M.; Chui, Granger K., "On-Board Diagnostics of Fuel Injector Clogging."

SAE Technical Paper 932421, Miller, James C.; Easterlund, Dean T., "Electrical Wiring Diagrams to Service Agricultural and Off-Highway Equipment: A Systematic Approach."

SAE Technical Paper 932404, Luebbering, Ben L.; Smith, Vern R., "Engine Electronics Technology."

SAE Technical Paper 930769, Rizzoni, Giorgio; Soliman, Ahmed; Passino, Kevin, "A Survey of Automotive Diagnostic Equipment and Procedures."

SAE Technical Paper 930464, Meyer, Roy; Kubesh, John T.; Shahed, S. M.; Davis, J. Keith, "Simultaneous Application of Optical Spark Plug Probe and Head Gasket Ionization Probe to a Production Engine."

SAE Technical Paper 930463, Lord, David L.; Anderson, Richard W.; Brehob, Diana D.; Kim, Youngil, "The Effects of Charge Motion on Early Flame Kernel Development."

SAE Technical Paper 930399, Klenk, Martin; Moser, Winfried; Mueller, Werner; Wimmer, Wolfgang, "Misfire Detection by Evaluating Crankshaft Speed - A Means to Comply with OBDII."

SAE Technical Paper 930246, Liang, Maurice Q., "Linking Diagnostics with Service Information."

SAE Technical Paper 930010, Millward, J. P., "Vehicle Electronic System Architectures Influences and Guidelines."

SAE Technical Paper 922498, Ferrone, Christopher W., "Global Vehicle Tracking and Computerized Vehicle Diagnostics; A Conceptual Discussion of a Future Integration."

SAE Technical Paper 921596, Bryant, Peter E., "A Review of the Potential for Vehicle On-Board Diagnostic Safety Systems."

SAE Technical Paper 921056, Walsh, Michael P.; Bradley, Michael, "A Comprehensive State Motor Vehicle Pollution Control Strategy for the 1990's and Beyond Part 1: Light Duty Vehicles."

SAE Technical Paper 920267, Kawahashi, Akira; Tsuji, Kimitoshi; Yokota, Hiroshi; Nobuhara, Yorikiyo, "Development of a Smart Analog Integrated Circuit for Electronic Control of an Automotive Variable Power-Steering System."

SAE Technical Paper 920236, Klauber, Robert D.; Vigmostad, Erik B.; Van Gerpen, Jon; Van Meter, Delmar; Sprague, Frederick P.; Reiter, Fred Jr., "Miniature Magnetostrictive Misfire Sensor."

SAE Technical Paper 920212, Inatsu, Hiroshi; Matsuo, Hiroki; Fujiwara, Kenichi; Yamada, Kenji; Nishizawa, Kazutoshi, "Development of Refrigerant Monitoring System for Automotive Air-Conditioning System."

SAE Technical Paper 920142, Tuteja, A. D.; Hoffman, M. B.; Lopez-Crevillen, J. M.; Singh, S.; Stomber, R. R.; Wallace, G. C., "Selection and Development of a Particulate Trap System for a Light Duty Diesel Engine."

SAE Technical Paper 920138, Norwich, W.; Skabowski, A.; Walsh, J.; Goldberger, L.; Keski-Hynnila, D.; Laymac, T.; Kojetin, P.; Ha, K.; Sumar, M., "Particulate Trap Technology Demonstration at New York City Transit Authority."

SAE Technical Paper 912848, Komanecky, Mark R.; Claus, David M., "IVHS Applications of Smart Cards."

SAE Technical Paper 912782, Phail, F., "The Power of a Personal Computer for Car Information and Communications Systems."

SAE Technical Paper 912683, Lukich, Janice M.; Brandt, Wayne D., "Integrated Diagnostics for the Vehicle System."

SAE Technical Paper 912433, Bogdanoff, Michael A.; Hada, Steven, "Overview of On-Board Diagnostic Systems Used on 1991 California Vehicles."

SAE Technical Paper 911831, Bulgrien, Garth H., "User-Friendly Electronic Powershift Transmission Controls."

SAE Technical Paper 911215, Kotzan, Joseph M., "On-Board Diagnostics for Emission Control Systems."

SAE Technical Paper 910874, Jennings, K.; Lynn, M.; Steele, R. E., "Bit-Wise Contention on Multi-Master Optical Networks.

SAE Technical Paper 910855, Mauer, Georg F., "On-Line Determination of Available Torque in Internal Combustion Engines."

SAE Technical Paper 910712, Louch, Robert J.; Franks, Donald C., "J1850 Multiplex Development Tools."

SAE Technical Paper 910638, Czarn, David A., "A Pressure Switch Manifold for Electronically Controlled Transmissions."

SAE Technical Paper 910561, Koupal, John W.; Sabourin, Michael A.; Clemmens, William B., "Detection of Catalyst Failure On-Vehicle Using the Dual Oxygen Sensor Method."

SAE Technical Paper 910277, Behr, Leonard W., "A Magnetically Damped Crash Sensor Providing Testability and Dynamic System Reconfiguration."

SAE Technical Paper 910254, Cai, Wei; Collings, Nick, "Unburnt Hydrocarbon Measurement by Means of a Surface Ionization Detector."

SAE Technical Paper 910253, Clark, Walter F.; Fortier, Robert J.; Coats, James M., "Ford Races its EEC-IV Electronic Engine Control Unit to Improve Production Vehicle Performance and Durability."

SAE Technical Paper 910069, Ribbens, William B., "A Mathematical Model Based Method for Diagnosing Failures in Automotive Electronic Systems."

SAE Technical Paper 910068, Derr, James H.; Louch, Robert J., "An Advanced Methodology for Projecting Field Repair Rates and Maintenance Costs for Vehicle Electronic Systems."

SAE Technical Paper 910040, Negishi, Satoshi; Takahashi, Kenzo; Yuyama, Toshio, "Data Recorder for Automotive Diagnosis."

SAE Technical Paper 902219, Ferrone, Christopher W., "Vehicle Diagnostics the Other Approach."

SAE Technical Paper 902218, Wing, R. Gregory; Uttamsingh, Ranjeet, "AI Based Diagnostic and Decision Support Systems for the Trucking Industry."

SAE Technical Paper 902217, White, Jon F.; Lackey, Lee, "A Universal Diagnostic Platform for the Heavy Truck Industry Background and Overview."

SAE Technical Paper 902216, Armstrong, Lee, "The Role of On-Board Computers and Networks for Fault Detection and Isolation."

SAE Technical Paper 902215, Stepper, Mark R., "Data Link Overview for Heavy Duty Vehicle Applications."

SAE Technical Paper 902213, Politz, W.; Leibbrand, N.; Tebbje, H., "The ABS 6S/4K a Modular System for Simplified Installation in Tractors, Semi-Trailers and Trailers."

SAE Technical Paper 902212, Moore, Tony; Kaess, Harald; Ruhnau, Gerhard, "SAE J1922 Data Link Control of Electronic Engine Torque Applied to Automatic Traction Control."

SAE Technical Paper 902210, Petersen, Erwin; Hesse, Karl-Heinz; Kaess, Harald; Lindemann, Klaus, "A New ABS with Intergral Automatic Traction Control for Air-Braked Trucks and Buses."

SAE Technical Paper 902207, Grimes, John F., "An Advanced Vehicle Instrumentation System."

SAE Technical Paper 901768, Rizzoni, Giorgio; Ribbens, William B., "On-Board Diagnosis of Engine Misfires."

SAE Technical Paper 901592, Ross, Larry F.; Panoushek, Dale W., "Adaptive Electronic Tractor Shift Control System."

SAE Technical Paper 901561, Macqueene, Jim; Nielson, Brad; Schwarz, Paul, "Development of the Electronic Draft Control System for the Ford New Holland 8210 Tractor."

SAE Technical Paper 901172, Onesti, Robert J.; Dannenberg, Robert D., "A Strategy for Diagnosing Modern Truck Electrical Systems."

SAE Technical Paper 901171, Cummings, Theodore; Hall, Michael J., "Vehicle Diagnostics A System View."

SAE Technical Paper 901170, Zwerner, John S.; Wright, C. David; Schmidt, Edward H., "Required Elements of Integrated Vehicle Control Systems."

SAE Technical Paper 901159, Hames, Richard J.; Henriksen, Craig O.; Bara, Mark F., "Field Experience with the Detroit Diesel Electronic Control System."

SAE Technical Paper 901158, Light, Dennis A.; Parupalli, Prasad V.; Luebbering, Ben L., "The Evolution of Electronic Engine Diagnostics."

SAE Technical Paper 901157, Bender, J. G.; Struthers, K. D., "Advanced Controls for Heavy Duty Transmission Applications."

SAE Technical Paper 901151, Tennant, Harry, "On-Board Knowledge Systems in Vehicles."

SAE Technical Paper 901150, Lecocq, Jean-Luc, "Intelligent Power Switches for Multiplexing."

SAE Technical Paper 901123, Baker, Milt; Puhl, Larry C.; Dabbish, Ezzy A.; Danielsen, Michael; Frank, Randy, "Sensing and Systems Aspects of Fault Tolerant Electronics Applied to Vehicle Systems."

SAE Technical Paper 900592, Bryden, William E.; Wilson, Mark L., "PT PACER - An Integrated Road Speed Governor."

SAE Technical Paper 900487, Watts, Robert J., "On-Line Detection of Vibration Damper Failure in Internal Combustion Engines."

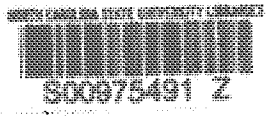
SAE Technical Paper 900232, Plapp, Gaxnther; Klenk, Martin; Moser, Winfried, "Methods of On-Board Misfire Detection."

SAE Technical Paper 900062, Clemmens, William B.; Sabourin, Michael A.; Rao, Thomas, "Detection of Catalyst Performance Loss Using On-Board Diagnostics."

ISBN 1-56091-549-8

OMEGA EXHIBIT 2037


NORTH CAROLINA STATE UNIVERSITY
THE LIBRARIES


S00975491 Z

SAE
On-Board Diagnostics for Light and Medium Duty Vehicles Standards Manual

1997 Edition

This book is due on the date indicated below and is subject to an overdue fine as posted at the circulation desk.

EXCEPTION: Date due will be earlier if this item is RECALLED.

SAE HS-3000

Published by:
Society of Automotive Engineers, Ir
400 Commonwealth Drive
Warrendale, PA 15096-0001
U.S.A.
Phone: (412) 776-4841
Fax: (412) 776-5760

1080/01-02--041880

All technical reports, including standards approved and practices recommended, are advisory only. Their use by anyone engaged in industry or trade or their use by governmental agencies is entirely voluntary. There is no agreement to adhere to any SAE Standard or Recommended Practice, and no commitment to conform to or be guided by any technical report. In formulating and approving technical reports, the Technical Board, its councils, and committees will not investigate or consider patents which may apply to the subject matter. Prospective users of the report are responsible for protecting themselves against liability for infringement of patents, trademarks, and copyrights.

Copyright © 1997 Society of Automotive Engineers, Inc.
ISBN 1-56091-924-8
All rights reserved. Printed in the United States of America.

Permission to photocopy for internal or personal use, or the internal or personal use of specific clients, is granted by SAE for libraries and other users registered with the Copyright Clearance Center (CCC), provided that the base fee of $.50 per page is paid directly to CCC, 222 Rosewood Dr., Danvers, MA 01923. Special requests should be addressed to the SAE Publications Group. 1-56091-924-8/97 $.50.

Table of Contents

1. Introduction v

2. SAE On-Board Diagnostics and Multiplex Technical Reports

2.1 Diagnostics Committee Documents

SAE J1930 SEP95 - Electrical/Electronic Systems Diagnostic Terms, Definitions, Abbreviations, and Acronyms 1
SAE J1962 JAN95 - Diagnostic Connector 19
SAE J1978 JUN94 - OBD II Scan Tool 25
SAE J1979 JUL96 - E/E Diagnostic Test Modes 29
SAE J2012 JUL96 - Recommended Practice for Diagnostic Trouble Code Definitions 39
SAE J2186 SEP91 - E/E Data Link Security 46
SAE J2190 JUN93 - Enhanced E/E Diagnostic Test Modes 48
SAE J2201 JUN93 - Universal Interface for OBD II Scan 65
SAE J2205 DEC95 - Expanded Diagnostic Protocol for OBD II Scan Tools 83

2.2 Multiplex Committee Documents

SAE J1850 JUL95 - Class B Data Communications Network Interface 91
SAE J2178/1 JAN95 - Class B Data Communication Network Messages— Detailed Header Formats and Physical Address Assignments 109
SAE J2178/2 JUN93 - Class B Data Communication Network Messages— Part 2: Data Parameter Definitions 116
SAE J2178/3 SEP93 - Class B Data Communication Network Messages— Part 3: Frame IDs for Single Byte Forms of Headers 137
SAE J2178/4 FEB95 - Class B Data Communication Network Messages— Message Definitions for Three Byte Headers 141

3. Bibliography of Related SAE Technical Papers 157

All technical reports, including standards approved and practices recommended, are advisory only. Their use by anyone engaged in industry or trade or their use by governmental agencies is entirely voluntary. There is no agreement to adhere to any SAE Standard or Recommended Practice, and no commitment to conform to or be guided by any technical report. In formulating and approving technical reports, the Technical Board, its councils, and committees will not investigate or consider patents which may apply to the subject matter. Prospective users of the report are responsible for protecting themselves against liability for infringement of patents, trademarks, and copyrights.

Copyright © 1997 Society of Automotive Engineers, Inc.
ISBN 1-56091-924-8
All rights reserved. Printed in the United States of America.

Permission to photocopy for internal or personal use, or the internal or personal use of specific clients, is granted by SAE for libraries and other users registered with the Copyright Clearance Center (CCC), provided that the base fee of $.50 per page is paid directly to CCC, 222 Rosewood Dr., Danvers, MA 01923. Special requests should be addressed to the SAE Publications Group. 1-56091-924-8/97 $.50.

Table of Contents

1. Introduction v

2. SAE On-Board Diagnostics and Multiplex Technical Reports

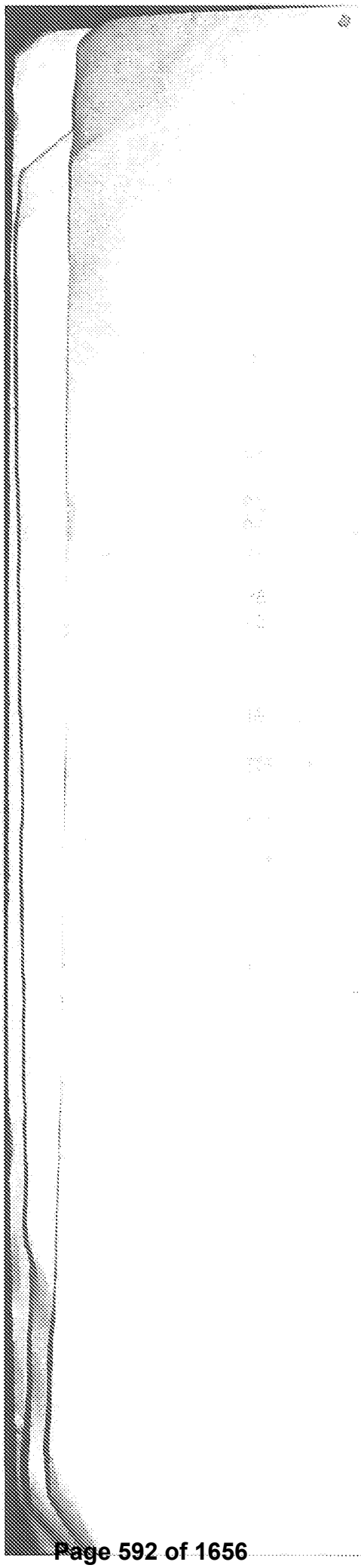
2.1 Diagnostics Committee Documents

SAE J1930 SEP95 - Electrical/Electronic Systems Diagnostic Terms, Definitions, Abbreviations, and Acronyms 1
SAE J1962 JAN95 - Diagnostic Connector 19
SAE J1978 JUN94 - OBD II Scan Tool 25
SAE J1979 JUL96 - E/E Diagnostic Test Modes 29
SAE J2012 JUL96 - Recommended Practice for Diagnostic Trouble Code Definitions 39
SAE J2186 SEP91 - E/E Data Link Security 46
SAE J2190 JUN93 - Enhanced E/E Diagnostic Test Modes 48
SAE J2201 JUN93 - Universal Interface for OBD II Scan 65
SAE J2205 DEC95 - Expanded Diagnostic Protocol for OBD II Scan Tools 83

2.2 Multiplex Committee Documents

SAE J1850 JUL95 - Class B Data Communications Network Interface 91
SAE J2178/1 JAN95 - Class B Data Communication Network Messages— Detailed Header Formats and Physical Address Assignments 109
SAE J2178/2 JUN93 - Class B Data Communication Network Messages— Part 2: Data Parameter Definitions 116
SAE J2178/3 SEP93 - Class B Data Communication Network Messages— Part 3: Frame IDs for Single Byte Forms of Headers 137
SAE J2178/4 FEB95 - Class B Data Communication Network Messages— Message Definitions for Three Byte Headers 141

3. Bibliography of Related SAE Technical Papers 157



Introduction

The SAE Vehicle E/E Systems Diagnostic Committee (Diagnostics Committee) was formed in June 1987 to address concerns of the automotive manufacturers and the automotive repair industry relating to repair of the increasingly complex electronic systems on new vehicles. The mission of this committee is:

> The committee shall increase customer satisfaction and lower product life cycle costs by investigating and recommending "standards" that will promote more effective diagnosis of vehicle electrical and electronic system problems.
>
> The resulting recommended practices will focus on model year 1992 and beyond. However, they may be useful for prior vehicle diagnosis/repair and may serve as a basis for additional recommended practices to pre-model year 1992 vehicles.

The committee adopted a "Vision of the Future" in July 1988. This vision, which has received very minor modifications, is:

> A standard diagnostic connector (in a standard location) will be in all vehicles. Pin assignments for a portion of the connector will be also standardized.
>
> All vehicles will implement a set of industry standard diagnostic test modes that can be executed over a standard communication data link (i.e., SAE J1850, ISO 9141-2). Industry standard test information will be associated with some of these diagnostic test modes.
>
> An OBD II "scan" tool will be able to utilize a minimum set of standardized diagnostic test modes and test information.
>
> A system will be in place that will allow standard "electronic" access of all E/E diagnostic service information.
>
> Future "diagnostic" legislation will be in harmony with this vision and the resulting SAE recommended practices.

The Diagnostics Committee originally combined the needs of the repair industry and the capabilities of the tool and automotive manufacturers to develop recommended practices to achieve the Mission of the Committee. Subsequent California ARB and EPA on-board diagnostic regulations have recognized the Vision of the Committee and reference recommended practices developed by the Committee.

There has been a great deal of cooperation between the regulatory agencies and the Diagnostics Committee to include regulated requirements in the recommended practices. Regulations and recommended practices have simultaneously evolved to eliminate discrepancies and to satisfy all requirements.

In addition to the Diagnostics Committee, the SAE Vehicle Networks for Multiplexing and Data Communication Committee (Multiplex Committee) has developed documents that are significant to meet On-Board Diagnostic regulations. SAE Standard J1850, "Class B Data Communication Network Interface," describes a diagnostic data link that can be used by the vehicle manufacturers to meet the on-board to off-board communication requirements of the regulations. SAE J2178 and SAE J1699 address usage and compliance issues of an SAE J1850 data link.

Some recommended practices have been developed in cooperation with the regulatory agencies, and in some attempt to achieve commonality beyond that which is mandated by regulations. The following table indicates the documents included in this Handbook Supplement, the 1997 SAE On-Board Diagnostics for Light and Medium Duty Vehicles Standards Manual (HS-3000), and their relationship to anticipated regulations at this time. Regulations are constantly under review and subject to change, so the reader should verify the contents of this table for accuracy when necessary.

	Mandated	Voluntary
On-Board	J1850 Communication Protocol J1962 Diagnostic Connector J1979 Diagnostic Test Modes J2012 Diagnostic Trouble Codes	J2178 Class B Messages J2186 Tamper Resistance (CARB) J2190 Enhanced Test Modes J1699 J1850 Verification
Off-Board	J1930 Terms and Definitions J1978 OBD II Scan Tool J2205 Expanded Scan Tool Protocol*	J2201 Scan Tool Interface* J2008 Service Info**

* Referenced in J1978, but not specifically referenced in regulations.
** Published as a Draft Technical Report —not included in this HS.

The International Organization for Standardization (ISO) Serial Data Communication Work Group (ISO/TC 22/SC 3/WG 1) has developed ISO 9141-2, "CARB Requirements for Interchange of digital information." This standard is allowed by OBD regulations as an alternative to SAE J1850 to meet diagnostic requirements. The ISO is also creating documents patterned after SAE documents. Some of the SAE Recommended Practices are being converted to ISO format, without technical changes, and are expected to be referenced in impending European regulations. Other ISO documents are being developed due to a desire to commonize diagnostic capabilities. The first of these documents are ISO 14299 (Diagnostic Services) and ISO 14230 (Keyword Protocol 2000).

Work on recommended practices is continuing in the Diagnostics Committee. Existing published documents are modified as needed to clarify specific sections or to expand the scope to meet revised regulations. New documents are developed as potential areas for standardization are identified. The SAE Committee and the ISO organization work closely together to ensure compatibility where possible.

ELECTRICAL/ELECTRONIC SYSTEMS DIAGNOSTIC TERMS, DEFINITIONS, ABBREVIATIONS, AND ACRONYMS—SAE J1930 SEP95

SAE Recommended Practice

Report of the SAE Vehicle E/E Systems Diagnostics Standards Committee approved June 1988, and completely revised September 1991 and June 1995. Revised by the J1930 Task Force of the SAE Vehicle E/E Systems Diagnostics Standards Committee September 1995.

Foreword—As the number of sophisticated electrical and electronic (E/E) systems on motor vehicles has increased, the number of terms, abbreviations, and acronyms which describe various components of these systems has increased enormously. To bring some order to the proliferation of such terms, abbreviations, and acronyms, the Vehicle E/E Diagnostic Systems Committee has prepared this document.

The nomenclature used to convey automotive service information is being standardized in order to more accurately convey information to technicians faced with the diagnosis and repair of increasingly complex vehicles.

To be properly descriptive, each type of automotive nomenclature requires a consistent methodology. This document is concerned with a methodology for naming objects and systems and with the set of words from which names are built.

The methodology allows objects and systems to be completely described without ambiguity. It also is able to generate names which distinguish among similar objects or systems without confusion but with brevity. Using terms which are well-defined within the context of the automotive service industry, the methodology allows already existing imprecise names to be suitably changed and future names to be assigned in a predictable way which will reliably convey meaning to the technician.

The structure of this SAE document is open ended by design. As the need arises, additional entries can be added. Because of this flexibility, particular attention should be paid to the month and year publishing code contained in the full "J" number designation.

TABLE OF CONTENTS

Foreword
1. Scope
2. References
3. How To Use This Document
4. Methodology
4.1 Naming Objects
4.1.1 Base Words
4.1.2 Modifiers
4.1.3 Technological Terms
4.2 Naming Systems
4.3 Shortened Names
4.3.1 Acronyms
4.3.2 Abbreviations
4.4 Indexing of Names
(R) 4.5 Alphanumeric Descriptors
5. Cross Reference and Look Up
6. Recommended Terms
7. Glossary of Terms
(R) 8. List Of Alphanumeric Descriptors
9. Revision Procedures
Appendix A

1. Scope—This SAE Recommended Practice is applicable to all light-duty gasoline and diesel passenger vehicles and trucks, and to heavy-duty gasoline vehicles. Specific applications of this document include diagnostic, service and repair manuals, bulletins and updates, training manuals, repair databases, under-hood emission labels, and emission certification applications.

This document focuses on diagnostic terms applicable to electrical/electronic systems, and therefore also contains related mechanical terms, definitions, abbreviations, and acronyms.

Even though the use and appropriate updating of this document is strongly encouraged, nothing in this document should be construed as prohibiting the introduction of a term, abbreviation, or acronym not covered by this document.

Certain terms have already been in common use and are readily understood by manufacturers and technicians, but do not follow the methodology of this document. To preserve this understanding, these terms were included and have been identified with the footnote (2), "historically acceptable common usage," so they will not erroneously serve as a precedent in the construction of new names. These terms fall into three categories:

a. Acronyms that do not logically fit the term.
b. Acronyms existing at the component level, i.e., their terms contain the base word or noun that describes the generic item that is being further defined.
c. Acronyms for terms that appear to contain the base word, but are frequently used as a modifier to another base word. (This use may possibly be thought of as following the methodology since the acronym is normally used as a modifier.)

2. References—There are no referenced publications specified herein.

3. How to Use This Document—To find the recommended term corresponding to an existing term, abbreviation or acronym, see Table 1, Cross Reference and Look Up. See Table 2, Recommended Terms, and Table 3, Glossary of Terms, for definitions of the recommended terms. Use Section 3.0, Methodology to construct a new name. Appropriate acceptable usage's of Recommended Terms and Acronyms are contained in Table 1.

4. Methodology—This naming methodology of describing objects and systems uses modifiers attached to base words. Appropriate modifiers are added to a base word until an object or system is uniquely specified within its context.

4.1 Naming Objects—When building names, select the most descriptive base word from the Glossary of Terms (Table 3). Add modifiers as necessary or as desirable within the context, in the order of most significance to least significance. The most significant word will be the base word, which denotes the basic function of the object. The most significant modifier will be adjacent to the base word, the second most significant will be next to that modifier, and so on until the least significant modifier is added. For the sake of future clarity, an additional modifier can be added to a name at any time, even if there is no present conflict with another object name. Figure 1 illustrates how modifiers can be added to build the name, "Instrumentation Engine Coolant Temperature Sensor."

When naming an object, it is tempting to choose the first modifiers according to the initial purpose for which the object was designed, but this will not always result in the name which is most helpful in the long run to a service technician. The information a technician needs is most often supplied by a term which describes a functional attribute, not purpose.

MODIFIERS				BASE WORD	
What is its purpose?	Where is it?	Which Temp?	What does it sense?	What is it?	
				Sensor	Most generic
			Temperature	Sensor	
		Coolant	Temperature	Sensor	
	Engine	Coolant	Temperature	Sensor	Most specific
Instrumentation	Engine	Coolant	Temperature	Sensor	

Least <---------- SIGNIFICANCE ----------> Most

FIGURE 1—MODIFIER USAGE EXAMPLE

To ensure accuracy, always check the Glossary definitions of base words and modifiers before including them in a name. The Glossary is intended for diagnostic purposes, but provides only electrical/electronic terms for base words. Base words which describe non-electrical objects (e.g., bolt, screw, bumper) should be used as in the past. Often, names for these objects are created by attaching the appropriate electrical/electronic object name to the mechanical base word. When using a common multiple word modifier, see Tables 1 and 2 to be sure that the modifier is acceptable or if it should be replaced with a more precise term.

4.1.1 BASE WORDS—The base word is the most generic term in a name. Simply stated, it answers the question, "What is this object?" In answering this question, the base word does not include information about the location or function of an object within a particular system. Specific information like this is provided by modifiers that are added to the base word. The following are examples of base words: diode, engine, module, motor, pump, relay, sensor, solenoid, switch, valve. The base word is always a noun and the last term in a name.

4.1.2 MODIFIERS—Modifiers provide functional/applicational meaning, system differentiation, and locational/ directional information. Modifiers usually express non-electrical ideas to describe base words which, in turn, convey electrical/electronic meaning. The range of modifiers is not limited and is used as necessary to uniquely describe an object in light of present knowledge, past experience, and potential future conflicts.

Although modifiers are used as adjectives, they are not necessarily terms which would normally be classified as adjectives. While neither "Air" or "Flow" are adjectives, the meaning of "Air Flow Valve" is clear to technicians; it is the name of a valve which regulates the flow of air. Both modifiers are nouns functioning as adjectives because of their position.

System modifiers can be added to object names to describe an object's purpose. When using a system name as a modifier in an object name, the word "System" is not included. For example, the device that directs the exhaust gases in the Exhaust Gas Recirculation (EGR) System is named "Exhaust Gas Recirculation (EGR) Valve."

4.1.3 TECHNOLOGICAL TERMS—Technologically specific terms tend to lengthen names without adding a corresponding level of useful service information about the function of an object. Add an appropriate technological modifier to a name only when it describes the primary difference between two objects. For example, the "thick film" technology used to construct the internal circuit of an Air Flow Sensor should not be identified in the object's name. However, if necessary for clarity, it would be appropriate to differentiate the relation to a specific external provision by adding "Hot Wire" to "Air Flow Sensor."

A technological term should be the first modifier conversationally (farthest from the base word, the position of least significance), unless a directional modifier is also present.

4.2 Naming Systems—When constructing a name for a system, consider it to be a combination of a "concept" and the word "System." Develop the concept name according to the rules for object naming and add the word "System." Keep in mind that a concept's most basic attribute is its purpose and that this attribute is described by the term closest to the word "System." For example, "recirculation" is the basic attribute of the Exhaust Gas Recirculation (EGR) concept. The group of components that embody the concept are together named the "EGR System."

4.3 Shortened Names—Techniques of shortening, including acronyms and abbreviations, are often necessary when space is limited and when names become awkwardly long. It is preferable to create a name first and its shortened form later, rather than the other way around.

Abbreviations and acronyms may be constructed not only of the letters of the alphabet, but of numbers, space characters, punctuation marks (such as "/" and "-"), subscripts and any other ASCII characters. Treat the individual acronyms, modifier abbreviations, and base word abbreviations as words, separating them by space characters.

4.3.1 ACRONYMS—Specific definitions of acronyms vary, but for the purpose of this document, an acronym is a memorable combination of the first letters of the words of a name. While abbreviations are useful in text where space is limited, acronyms are particularly convenient for shortening verbal communication in addition to written materials. For this reason, acronyms are often pronounceable, which also makes them easy to remember. They are especially useful if a name is long and bulky both on paper and in conversation.

Use acronyms as modifiers or base words within names, such as "EGR System" and "Primary ECM." Do not use them as entire names, like "EGR". Acronyms and other modifiers may be combined in any meaningful order to modify a base word. The following are examples of acceptable uses of acronyms:

EGR System EGRT Sensor Low Speed FC Switch High Speed FC Switch

Because there are a limited number of useful letter combinations in acronyms, new acronyms should be created for only the most commonly used terms. Also, avoid creating new acronyms by adding letters to those that already exist. For example, when using the acronym "FC" (Fan Control), do not add "H" or "L" to indicate "High Speed" or "Low Speed." Instead, use additional modifiers.

Usually, the first letters of each word of a name are used to build an acronym, but if a particular word is of little significance, it may be omitted ("United States of America" becomes "USA"). Also, more than the first letter of each word may be used ("Radio Detecting And Ranging" becomes "RADAR"). An acronym like "USA" which contains three letters or fewer may have its letters spoken separately, but a longer acronym such as "RADAR" must be pronounceable or its purpose will be defeated.

All of the letters of an acronym should be capitalized. Acronyms should not contain periods. Until an acronym is widely well-known, it should be accompanied by the spelled-out form when necessary for accurate reader comprehension in any given context.

In the very rare cases of strong historical meaning across all manufacturers, the rules for naming and acronym usage may be broken. For example, "AIR" is the approved acronym for "Secondary Air Injection," instead of "SAI." In fact, because there is no approved name "Primary Air Injection," the term "Secondary Air Injection" would be considered inappropriate. Despite this, historical precedent renders "AIR" and "Secondary Air Injection" the most easily understood terms. "AIR" originally meant "Air Injection Reactor." However, vehicles no longer necessarily use a separate air injector reactor, but instead might have additional air injected to the catalytic converter. Because of the similarity to the previous system, technicians have expressed a strong desire to retain "AIR" rather than "SAI."

Before using a new acronym, be sure to check Tables 1 and 2 for any conflicts with acronyms already in use.

4.3.2 ABBREVIATIONS—Use abbreviations to shorten base words and directional modifiers in written materials. Unlike an acronym, an abbreviation should have only its first letter capitalized and should end with a period. Wire colors are an exception to the rules of capitalization and punctuation. As in the past, they should continue to be completely capitalized in text and not followed by a period (for example, "a BLK wire"). Currently identified abbreviations for base words and modifiers are found in Table 1.

4.4 Indexing of Names—Service information index designers consider the importance of each term in a name, and select the most appropriate word(s) to index. They most frequently index base words, following each by its modifier(s) to enhance users retrieval. This document allows the designer flexibility to choose the indexed word(s); while it describes, in detail, the methodology for the conversational word order in text and illustrations. For example, the designer can conform to the methodology of this document and provide the user with the effective retrieval of the conversational name "Left Front Wheel Speed Sensor" by indexing it as "Sensor, Left Front Wheel Speed."

(R) 4.5 Alphanumeric Descriptors—Sections 4.1 through 4.3 describe the appropriate methodology to completely described object and system without ambiguity. This section includes naming objects (with base words, modifiers, and technological terms), naming systems and building shortened names.

An "alphanumeric descriptor" can be used in information delivered to the end-user of a scan tool having an 8-character display limitation. An alphanumeric descriptor is not recommended for general use, but can be built from a Recommended Term by replacing position modifier words with numeric digits, and omitting certain self-evident letters.

Alphanumeric position modifiers in an alphanumeric descriptor should be positioned to follow the base word, rather than the conversational practice of preceding the base word.

Figure 2 illustrates how several Recommended Terms and Acronyms can be further shortened into alphanumeric descriptors.

The following guidelines should be followed when using or developing alphanumeric descriptors:

a. First consult Table 2, Recommended Terms in the Acronyms column.
b. If the term is not included, build a suitable term using 4.1 Naming Object or 4.2 Naming System. Then shorten the term using 4.3 Shortened Names.
c. If the resultant term is too long for a scan tool with an 8-character display limitation, build an Alphanumeric Descriptor for electronic delivery according to the pattern shown in Figure 2:
d. Delete or replace characters as required.
e. Omit spaces depending on the display limitation.
(example: FUEL PRES becomes FUELPRES)
f. Consult Table 4 for a matching Alphanumeric Descriptor.
g. If Table 4 does not contain a matching Alphanumeric Descriptor, request an addition, using the Request for Revision form in Appendix A.

5. Cross Reference and Look Up—See Table 1. The left column lists existing terms, acronyms and abbreviations. The center column provides the corresponding acceptable usage's constructed of recommended terms combined with other modifiers and/or base words. The acceptable acronized usage is shown in the right column.

For information about using acronyms and abbreviations, see 4.3.1 (Acronyms) and 4.3.2 (Abbreviations). For additional information about recommended Terms, see Tables 2 and 3.

Recommended Term	Acceptable Acronized Usage	Alphanumeric Descriptor
Diagnostic Trouble Code Freeze Frame	DTC Freeze Frame	DTC FRZF
Engine Coolant Temperature	ECT	None Required
Flexible Fuel	FF	None Required
Freeze Frame	Freeze Frame	FRZF
Fuel Pressure	Fuel Pressure	FUEL PRES
Fuel System 1 Status	Fuel System 1 Status	FUEL SYS1
Long Term Fuel Trim Bank 2	Long Term FT Bank 2	LONG FT2
Oxygen Sensor Location Bank 1 Position 1	OBS Bank 1 Position 1	O2SLOC11

FIGURE 2—ALPHANUMERIC DESCRIPTORS EXAMPLE

TABLE 1—CROSS REFERENCE AND LOOK UP

Existing Usage	Acceptable Usage	Acceptable Acronized Usage
A/C (Air Conditioning)	Air Conditioning	AC
A/C Cycling Switch	Air Conditioning Cycling Switch	AC Cycling Switch
A/T (Automatic Transaxle)	Automatic Transaxle[1]	AT[1]
A/Y (Automatic Transmission)	Automatic Transmission[1]	AT[1]
AAT (Ambient Air Temperature)	Ambient Air Temperature	AAT
AC (Air Conditioning)	Air Conditioning	AC
ACC (Air Conditioning Clutch)	Air Conditioning Clutch	AC Clutch
Accelerator	Accelerator Pedal	AP
Accelerator Pedal Position	Accelerator Pedal Position[1]	APP[1]
ACCS (Air Conditioning Cycle Switch)	Air Conditioning Cycling Switch	AC Cycling Switch
ACH (Air Cleaner Housing)	Air Cleaner Housing[1]	ACL Housing[1]
ACL (Air Cleaner)	Air Cleaner[1]	ACL[1]
ACL (Air Cleaner) Element	Air Cleaner Element[1]	ACL Element[1]
ACL (Air Cleaner) Housing	Air Cleaner Housing[1]	ACL Housing[1]
ACL (Air Cleaner) Housing Cover	Air Cleaner Housing Cover[1]	ACL Housing Cover[1]
ACS (Air Conditioning System)	Air Conditioning System	AC System
ACT (Air Charge Temperature)	Intake Air Temperature[1]	IAT[1]
Adaptive Fuel Strategy	Fuel Trim[1]	FT[1]
AFC (Air Flow Control)	Mass Air Flow	MAF
AFC (Air Flow Control)	Volume Air Flow	VAF
AFS (Air Flow Sensor)	Mass Air Flow Sensor	MAF Sensor
AFS (Air Flow Sensor)	Volume Air Flow Sensor	VAF Sensor
After Cooler	Charge Air Cooler[1]	CAC[1]
AI (Air Injection)	Secondary Air Injection[1]	AIR[1]
AIP (Air Injection Pump)	Secondary Air Injection Pump[1]	AIR Pump[1]
AIR (Air Injection Reactor)	Pulsed Secondary Air Injection[1]	PAIR[1]
AIR (Air Injection Reactor)	Secondary Air Injection[1]	AIR[1]
AIRB (Secondary Air Injection Bypass)	Secondary Air Injection Bypass[1]	AIR Bypass[1]
AIRD (Secondary Air Injection Diverter)	Secondary Air Injection Diverter[1]	AIR Diverter[1]
Air Cleaner	Air Cleaner[1]	ACL[1]
Air Cleaner Element	Air Cleaner Element[1]	ACL Element[1]
Air Cleaner Housing	Air Cleaner Housing[1]	ACL Housing[1]
Air Cleaner Housing Cover	Air Cleaner Housing Cover[1]	ACL Housing Cover[1]
Air Conditioning	Air Conditioning	AC
Air Conditioning Sensor	Air Conditioning Sensor	AC Sensor
Air Control Valve	Secondary Air Injection Control Valve[1]	AIR Control Valve[1]
Air Flow Meter	Mass Air Flow Sensor[1]	MAF Sensor[1]
Air Flow Meter	Volume Air Flow Sensor[1]	VAF Sensor[1]
Air Intake System	Intake Air System[1]	IA System[1]
Air Flow Sensor	Mass Air Flow Sensor[1]	MAF Sensor[1]
Air Management 1	Secondary Air Injection Bypass[1]	AIR Bypass[1]
Air Management 2	Secondary Air Injection Diverter[1]	AIR Diverter[1]
Air Temperature Sensor	Intake Air Temperature Sensor[1]	IAT Sensor[1]
Air Valve	Idle Air Control Valve[1]	IAC Valve[1]
AIV (Air Injection Valve)	Pulsed Secondary Air Injection[1]	PAIR[1]
ALCL (Assembly Line Communication Link)	Data Link Connector[1]	DLC[1]
Alcohol Concentration Sensor	Flexible Fuel Sensor[1]	FF Sensor[1]
ALDL (Assembly Line Diagnostic Link)	Data Link Connector[1]	DLC[1]
ALT (Alternator)	Generator	GEN
Alternator	Generator	GEN
Ambient Air Temperature	Ambient Air Temperature	AAT
AM1 (Air Management 1)	Secondary Air Injection Bypass[1]	AIR Bypass[1]
AM2 (Air Management 2)	Secondary Air Injection Diverter[1]	AIR Diverter[1]

TABLE 1—CROSS REFERENCE AND LOOK UP (CONTINUED)

Existing Usage	Acceptable Usage	Acceptable Abbreviated Usage
APP (Accelerator Pedal Position)	Accelerator Pedal Position[1]	APP[1]
APS (Absolute Pressure Sensor)	Barometric Pressure Sensor[1]	BARO Sensor[1]
ATS (Air Temperature Sensor)	Intake Air Temperature Sensor[1]	IAT Sensor[1]
Automatic Transaxle	Automatic Transaxle[1]	A/T[1]
Automatic Transmission	Automatic Transmission[1]	A/T[1]
B+ (Battery Positive Voltage)	Battery Positive Voltage	B+
Backpressure Transducer	Exhaust Gas Recirculation Backpressure Transducer[1]	EGR Backpressure Transducer[1]
BARO (Barometric Pressure)	Barometric Pressure[1]	BARO[1]
Barometric Pressure Sensor	Barometric Pressure Sensor[1]	BARO Sensor[1]
Battery Positive Voltage	Battery Positive Voltage	B+
BLM (Block Learn Memory)	Long Term Fuel Trim[1]	Long Term FT[1]
BLM (Block Learn Multiplier)	Long Term Fuel Trim[1]	Long Term FT[1]
BLM (Block Learn Matrix)	Long Term Fuel Trim[1]	Long Term FT[1]
Block Learn Integrator	Long Term Fuel Trim[1]	Long Term FT[1]
Block Learn Matrix	Long Term Fuel Trim[1]	Long Term FT[1]
Block Learn Memory	Long Term Fuel Trim[1]	Long Term FT[1]
Block Learn Multiplier	Long Term Fuel Trim[1]	Long Term FT[1]
BP (Barometric Pressure) Sensor	Barometric Pressure Sensor[1]	BARO Sensor[1]
BPP (Brake Pedal Position)	Brake Pedal Position[1]	BPP[1]
Brake Pressure	Brake Pressure	Brake Pressure
Brake Pedal Position	Brake Pedal Position[1]	BPP[1]
CSI (Computer Controlled Coil Ignition)	Electronic Ignition[1]	EI[1]
CAC (Charge Air Cooler)	Charge Air Cooler[1]	CAC[1]
Calculated Load Value	Calculated Load Value	CLV
Camshaft Position	Camshaft Position[1]	CMP[1]
Camshaft Position Actuator	Camshaft Position Actuator[1]	CMP Actuator[1]
Camshaft Position Controller	Camshaft Position Actuator[1]	CMP Actuator[1]
Camshaft Position Sensor	Camshaft Position Sensor[1]	CMP Sensor[1]
Camshaft Sensor	Camshaft Position Sensor[1]	CMP Sensor[1]
Camshaft Timing Actuator	Camshaft Position Actuator[1]	CMP Actuator[1]
Canister	Canister[1]	Canister[1]
Canister	Evaporative Emission Canister[1]	EVAP Canister[1]
Canister Purge	Evaporative Emission Canister Purge[1]	EVAP Canister Purge[1]
Canister Purge Vacuum Switching Valve	Evaporative Emission Canister Purge Valve[1]	EVAP Canister Purge Valve[1]
Canister Purge Valve	Evaporative Emission Canister Purge Valve[1]	EVAP Canister Purge Valve[1]
Canister Purge VSV (Vacuum Switching Valve)	Evaporative Emission Canister Purge Valve[1]	EVAP Canister Purge Valve[1]
CANP (Canister Purge)	Evaporative Emission Canister Purge[1]	EVAP Canister Purge[1]
CARB (Carburetor)	Carburetor[1]	CARB[1]
Carburetor	Carburetor[1]	CARB[1]
Catalytic Converter Heater	Catalytic Converter Heater	Catalytic Converter Heater
CCC (Converter Clutch Control)	Torque Converter Clutch[1]	TCC[1]
CCO (Converter Clutch Override)	Torque Converter Clutch[1]	TCC[1]
CCS (Coast Clutch Solenoid)	Coast Clutch Solenoid	CCS
CCSV (Coast Clutch Solenoid) Valve	Coast Clutch Solenoid Valve	CCS Valve
CCRM (Constant Control Relay Module)	Constant Control RM	Constant Control RM
CDI (Capacitive Discharge Ignition)	Distributor Ignition[1]	DI[1]
CDROM (Compact Disc Read Only Memory)	Compact Disc Read Only Memory[1]	CDROM[1]
CES (Clutch Engage Switch)	Clutch Pedal Position Switch	CPP Switch[1]
Central Multiport Fuel Injection	Central Multiport Fuel Injection[1]	Central MFI[1]
Central Sequential Multiport Fuel Injection	Central Sequential Multiport Fuel Injection	Central SFI
CFI (Continuous Fuel Injection)	Continuous Fuel Injection[1]	CFI[1]
CFI (Central Fuel Injection)	Throttle Body Fuel Injection[1]	TBI[1]
CFV	Critical Flow Venturi	CFV
Charcoal Canister	Evaporative Emission Canister	EVAP Canister[1]
Charge Air Cooler	Charge Air Cooler	CAC[1]
Check Engine	Service Reminder Indicator[1]	SRI[1]
Check Engine	Malfunction Indicator Lamp[1]	MIL[1]
CID (Cylinder Identification) Sensor	Camshaft Position Sensor	CMP Sensor[1]
CIS (Continuous Injection System)	Continuous Fuel Injection[1]	CFI[1]
CIS-E (Continuous Injection System Electronic)	Continuous Fuel Injection[1]	CFI[1]
CKP (Crankshaft Position)	Crankshaft Position[1]	CKP[1]
CKP (Crankshaft Position) Sensor	Crankshaft Position Sensor[1]	CKP Sensor[1]
CL (Closed Loop)	Closed Loop[1]	CL[1]
Closed Bowl Distributor	Distributor Ignition[1]	DI[1]
Closed Throttle Position	Closed Throttle Position[1]	CTP[1]
Closed Throttle Switch	Closed Throttle Position Switch[1]	CTP Switch[1]
CLS (Closed Loop System)	Closed Loop[1]	CL[1]
CLV	Calculated Load Value	CLV
Clutch Engage Switch	Clutch Pedal Position Switch[1]	CPP Switch[1]
Clutch Pedal Position Switch	Clutch Pedal Position Switch[1]	CPP Switch[1]
Clutch Start Switch	Clutch Pedal Position Switch[1]	CPP Switch[1]
Clutch Switch	Clutch Pedal Position Switch[1]	CPP Switch[1]
CMFI (Central Multiport Fuel Injection)	Central Multiport Fuel Injection[1]	Central MFI[1]
CMP (Camshaft Position)	Camshaft Position[1]	CMP[1]
CMP (Camshaft Position) Sensor	Camshaft Position Sensor[1]	CMP Sensor[1]
CCO (Continuous Oxidation Catalyst)	Oxidation Catalytic Converter[1]	OC[1]
Coast Clutch Solenoid	Coast Clutch Solenoid	CCS
Coast Clutch Solenoid Valve	Coast Clutch Solenoid Valve	CCS Valve
Condenser	Distributor Ignition Capacitor[1]	DI Capacitor[1]
Constant Control Relay Module	Relay Module	RM
Constant Volume Sampler	Constant Volume Sampler	CVS

TABLE 1—CROSS REFERENCE AND LOOK UP (CONTINUED)

Existing Usage	Acceptable Usage	Acceptable Acronym/ Usage
Continuous Fuel Injection	Continuous Fuel Injection[1]	CFI[1]
Continuous Injection System	Continuous Fuel Injection System[1]	CFI System[1]
Continuous Injection System-E	Electronic Continuous Fuel Injection System[1]	Electronic CFI System[1]
Continuous Trap Oxidizer	Continuous Trap Oxidizer[1]	CTOX[1]
Coolant Temperature Sensor	Engine Coolant Temperature Sensor[1]	ECT Sensor[1]
CP (Crankshaft Position)	Crankshaft Position[1]	CKP[1]
CPP (Clutch Pedal Position)	Clutch Pedal Position[1]	CPP[1]
CPP (Clutch Pedal Position) Switch	Clutch Pedal Position Switch	CPP Switch[1]
CPS (Camshaft Position Sensor)	Camshaft Position Sensor[1]	CMP Sensor[1]
CPS (Crankshaft Position Sensor)	Crankshaft Position Sensor[1]	CKP Sensor[1]
Crank Angle Sensor	Crankshaft Position Sensor[1]	CKP Sensor[1]
Crankshaft Position	Crankshaft Position[1]	CKP[1]
Crankshaft Position Sensor	Crankshaft Position Sensor[1]	CKP Sensor[1]
Crankshaft Speed	Engine Speed[1]	RPM[1]
Crankshaft Speed Sensor	Engine Speed Sensor[1]	RPM Sensor[1]
Critical Flow Venturi	Critical Flow Venturi	CFV
CTO (Continuous Trap Oxidizer)	Continuous Trap Oxidizer[1]	CTOX[1]
CTOX (Continuous Trap Oxidizer)	Continuous Trap Oxidizer[1]	CTOX[1]
CTP (Closed Throttle Position)	Closed Throttle Position[1]	CTP[1]
CTS (Coolant Temperature Sensor)	Engine Coolant Temperature Sensor[1]	ECT Sensor[1]
CTS (Coolant Temperature Switch)	Engine Coolant Temperature Switch[1]	ECT Switch[1]
CVS	Constant Volume Sampler	CVS
Cylinder ID (Identification) Sensor	Camshaft Position Sensor[1]	CMP Sensor[1]
D-Jetronic	Multiport Fuel Injection[1]	MFI[1]
Data Link Connector	Data Link Connector[1]	DLC[1]
Detonation Sensor	Knock Sensor[1]	KS[1]
DFI (Direct Fuel Injection)	Direct Fuel Injection[1]	DFI[1]
DFI (Digital Fuel Injection)	Multiport Fuel Injection[1]	MFI[1]
DI (Direct Injection)	Direct Fuel Injection[1]	DFI[1]
DI (Distributor Ignition)	Distributor Ignition[1]	DI[1]
DI (Distributor Ignition) Capacitor	Distributor Ignition Capacitor[1]	DI Capacitor[1]
Diagnostic Test Mode	Diagnostic Test Mode[1]	DTM[1]
Diagnostic Trouble Code	Diagnostic Trouble Code[1]	DTC[1]
DID (Direct Injection - Diesel)	Direct Fuel Injection[1]	DFI[1]
Differential Pressure Feedback EGR (Exhaust Gas Recirculation) System	Differential Pressure Feedback Exhaust Gas Recirculation System[1]	Differential Pressure Feedback EGR System[1]
Digital EGR (Exhaust Gas Recirculation)	Exhaust Gas Recirculation[1]	EGR[1]
Direct Fuel Injection	Direct Fuel Injection[1]	DFI[1]
Direct Ignition System	Electronic Ignition System[1]	EI System[1]
DIS (Distributorless Ignition System)	Electronic Ignition System[1]	EI System[1]
DIS (Distributorless Ignition System) Module	Ignition Control Module[1]	ICM[1]
Distance Sensor	Vehicle Speed Sensor[1]	VSS[1]
Distributor Ignition	Distributor Ignition[1]	DI[1]
Distributorless Ignition	Electronic Ignition[1]	EI[1]
DLC (Data Link Connector)	Data Link Connector[1]	DLC[1]
DLI (Distributorless Ignition)	Electronic Ignition[1]	EI[1]
Driver	Driver	Driver
DS (Detonation Sensor)	Knock Sensor[1]	KS[1]
DTC (Diagnostic Trouble Code)	Diagnostic Trouble Code[1]	DTC[1]
DTM (Diagnostic Test Mode)	Diagnostic Test Mode[1]	DTM[1]
Dual Bed	Three Way + Oxidation Catalytic Converter[1]	TWC+OC[1]
Duty Solenoid for Purge Valve	Evaporative Emission Canister Purge Valve	EVAP Canister Purge Valve[1]
Dynamic Pressure Control	Dynamic Pressure Control	Dynamic PC
Dynamic Pressure Control Solenoid	Dynamic Pressure Control Solenoid[1]	Dynamic PC Solenoid[1]
Dynamic Pressure Control Solenoid Valve	Dynamic Pressure Control Solenoid Valve[1]	Dynamic PC Solenoid Valve[1]
E2PROM (Electrically Erasable Programmable Read Only Memory)	Electrically Erasable Programmable Read Only Memory[1]	EEPROM[1]
Early Fuel Evaporation	Early Fuel Evaporation[1]	EFE[1]
EATX (Electronic Automatic Transmission/ Transaxle)	Automatic Transmission[1]	AT[1]
EC (Engine Control)	Engine Control[1]	EC[1]
ECA (Electronic Control Assembly)	Powertrain Control Module[1]	PCM[1]
ECL (Engine Coolant Level)	Engine Coolant Level	ECL
ECM (Engine Control Module)	Engine Control Module[1]	ECM[1]
ECT (Engine Coolant Temperature)	Engine Coolant Temperature[1]	ECT[1]
ECT (Engine Coolant Temperature) Sender	Engine Coolant Temperature Sensor[1]	ECT Sensor[1]
ECT (Engine Coolant Temperature) Sensor	Engine Coolant Temperature Sensor[1]	ECT Sensor[1]
ECT (Engine Coolant Temperature) Switch	Engine Coolant Temperature Switch[1]	ECT Switch[1]
ECUA (Electronic Control Unit A)	Powertrain Control Module[1]	PCM[1]
EDF (Electro-Drive Fan) Control	Fan Control	FC
EDIS (Electronic Distributor Ignition System)	Distributor Ignition System[1]	DI System[1]
EDIS (Electronic Distributorless Ignition System)	Electronic Ignition System[1]	EI System[1]
EDIS (Electronic Distributor Ignition System) Module	Distributor Ignition Control Module[1]	Distributor ICM[1]
EEC (Electronic Engine Control)	Engine Control[1]	EC[1]
EEC (Electronic Engine Control) Processor	Powertrain Control Module[1]	PCM[1]
EEDS (Evaporative Emission Control System)	Evaporative Emission System[1]	EVAP System[1]
EEPROM (Electrically Erasable Programmable Read Only Memory)	Electrically Erasable Programmable Read Only Memory[1]	EEPROM[1]
EFE (Early Fuel Evaporation)	Early Fuel Evaporation[1]	EFE[1]
EFI (Electronic Fuel Injection)	Multiport Fuel Injection[1]	MFI[1]
EFI (Electronic Fuel Injection)	Throttle Body Fuel Injection[1]	TBI[1]
EGO (Exhaust Gas Oxygen) Sensor	Oxygen Sensor[1]	HO2S[1]

TABLE 1—OBD-II REFERENCE AND LOOK UP (CONTINUED)

Existing Usage	Acceptable Usage	Acceptable Abbreviated Usage
EGOS (Exhaust Gas Oxygen Sensor)	Oxygen Sensor[1]	O2S[1]
EGR (Exhaust Gas Recirculation)	Exhaust Gas Recirculation[1]	EGR[1]
EGR (Exhaust Gas Recirculation) Diagnostic Valve	Exhaust Gas Recirculation Diagnostic Valve[1]	EGR Diagnostic Valve[1]
EGR (Exhaust Gas Recirculation) System	Exhaust Gas Recirculation System[1]	EGR System[1]
EGR (Exhaust Gas Recirculation) Thermal Vacuum Valve	Exhaust Gas Recirculation Thermal Vacuum Valve[1]	EGR TVV[1]
EGR (Exhaust Gas Recirculation) Valve	Exhaust Gas Recirculation Valve[1]	EGR Valve[1]
EGR TVV (Exhaust Gas Recirculation Thermal Vacuum Valve)	Exhaust Gas Recirculation Thermal Vacuum Valve[1]	EGR TVV[1]
EGRT (Exhaust Gas Recirculation Temperature)	Exhaust Gas Recirculation Temperature	EGRT[1]
EGRT (Exhaust Gas Recirculation Temperature) Sensor	Exhaust Gas Recirculation Temperature Sensor[1]	EGRT Sensor[1]
EGRV (Exhaust Gas Recirculation Valve)	Exhaust Gas Recirculation Valve[1]	EGR Valve[1]
EGRVC (Exhaust Gas Recirculation Valve Control)	Exhaust Gas Recirculation Valve Control[1]	EGR Valve Control[1]
EGS (Exhaust Gas Sensor)	Oxygen Sensor[1]	O2S[1]
EI (Electronic Ignition) (With Distributor)	Distributor Ignition[1]	DI[1]
EI (Electronic Ignition) (Without Distributor)	Electronic Ignition[1]	EI[1]
Electrically Erasable Programmable Read Only Memory	Electrically Erasable Programmable Read Only Memory[1]	EEPROM[1]
Electronic Engine Control	Electronic Engine Control[1]	Electronic EC[1]
Electronic Ignition	Electronic Ignition[1]	EI[1]
Electronic Spark Advance	Ignition Control[1]	EC[1]
Electronic Spark Timing	Ignition Control[1]	EC[1]
EM (Engine Modification)	Engine Modification[1]	EM[1]
EMR (Engine Maintenance Reminder)	Engine Reminder Indicator[1]	MIL[1]
Engine Control	Engine Control[1]	EC[1]
Engine Coolant Fan Control	Fan Control	FC[1]
Engine Coolant Level	Engine Coolant Level	ECL[1]
Engine Coolant Level Indicator	Engine Coolant Level Indicator	ECL Indicator
Engine Coolant Temperature	Engine Coolant Temperature[1]	ECT[1]
Engine Coolant Temperature Sender	Engine Coolant Temperature Sender[1]	ECT Sender[1]
Engine Coolant Temperature Sensor	Engine Coolant Temperature Sensor[1]	ECT Sensor[1]
Engine Coolant Temperature Switch	Engine Coolant Temperature Switch[1]	ECT Switch[1]
Engine Modification	Engine Modification[1]	EM[1]
Engine Oil Pressure Sender	Engine Oil Pressure Sensor	EOP Sender
Engine Oil Pressure Sensor	Engine Oil Pressure Sensor	EOP Sensor
Engine Oil Pressure Switch	Engine Oil Pressure Switch	EOP Switch
Engine Oil Temperature	Engine Oil Temperature	EOT[1]
Engine Speed	Engine Speed[1]	ES[1]
EOS (Exhaust Oxygen Sensor)	Oxygen Sensor[1]	O2S[1]
EOT (Engine Oil Temperature)	Engine Oil Temperature	EOT[1]
EP (Exhaust Pressure)	Exhaust Pressure	EP[1]
EPROM (Erasable Programmable Read Only Memory)	Erasable Programmable Read Only Memory[1]	EPROM[1]
Erasable Programmable Read Only Memory	Erasable Programmable Read Only Memory[1]	EPROM[1]
ESA (Electronic Spark Advance)	Ignition Control[1]	EC[1]
ESAC (Electronic Spark Advance Control)	Distributor Ignition[1]	DI[1]
EST (Electronic Spark Timing)	Ignition Control[1]	EC[1]
EVAP (Evaporative Emission) CANP (Canister Purge)	Evaporative Emission Canister Purge[1]	EVAP Canister Purge[1]
EVAP (Evaporative Emission)	Evaporative Emission[1]	EVAP[1]
EVAP (Evaporative Emission) Canister	Evaporative Emission Canister[1]	EVAP Canister[1]
EVAP (Evaporative Emission) Purge Valve	Evaporative Emission Canister Purge Valve[1]	EVAP Canister Purge Valve[1]
Evaporative Emission	Evaporative Emission[1]	EVAP[1]
Evaporative Emission Canister	Evaporative Emission Canister[1]	EVAP Canister[1]
EVP (Exhaust Gas Recirculation Valve Position) Sensor	Exhaust Gas Recirculation Valve Position Sensor[1]	EGR Valve Position Sensor[1]
EVR (Exhaust Gas Recirculation Vacuum Regulator) Solenoid	Exhaust Gas Recirculation Vacuum Regulator Solenoid[1]	EGR Vacuum Regulator Solenoid[1]
EVRV (Exhaust Gas Recirculation Vacuum Regulator Valve)	Exhaust Gas Recirculation Vacuum Regulator Valve[1]	EGR Vacuum Regulator Valve[1]
Exhaust Gas Recirculation	Exhaust Gas Recirculation[1]	EGR[1]
Exhaust Gas Recirculation Temperature	Exhaust Gas Recirculation Temperature[1]	EGRT[1]
Exhaust Gas Recirculation Temperature Sensor	Exhaust Gas Recirculation Temperature Sensor[1]	EGRT Sensor[1]
Exhaust Gas Recirculation Vacuum Solenoid Valve Regulator	Exhaust Gas Recirculation Vacuum Regulator Solenoid Valve[1]	EGR Vacuum Regulator Solenoid Valve[1]
Exhaust Gas Recirculation Vacuum Regulator Valve	Exhaust Gas Recirculation Vacuum Regulator Valve[1]	EGR Vacuum Regulator Valve[1]
Exhaust Gas Recirculation Valve	Exhaust Gas Recirculation Valve[1]	EGR Valve[1]
Exhaust Pressure	Exhaust Pressure	EP[1]
4GR (Fourth Gear)	Fourth Gear	4GR
4WD (Four Wheel Drive)	Full Time Four Wheel Drive	4WD
4WD (Four Wheel Drive)	Intermittent Four Wheel Drive	4WD
FWD	Part Time Four Wheel Drive	4WD
Fan Control	Fan Control	FC[1]
Fan Control Module	Fan Control Module	FC Module
Fan Control Relay	Fan Control Relay	FC Relay
Fan Motor Control Relay	Fan Control Relay	FC Relay
Fast Idle Thermo Valve	Idle Air Control Thermal Valve[1]	IAC Thermal Valve[1]
FBC (Feed Back Carburetor)	Refueling[1]	FUEL[1]
FBC (Feed Back Control)	Mixture Control	MC[1]
FC (Fan Control)	Fan Control	FC[1]
FC2 (Fan Control) Relay	Fan Control Relay	FC Relay

TABLE 1—CROSS REFERENCE AND LOOK UP (CONTINUED)

Rotating Usage	Acceptable Usage	Acceptable Abbreviated Usage
FEEPROM (Flash Electrically Erasable Programmable Read Only Memory)	Flash Electrically Erasable Programmable Read Only Memory[1]	FEEPROM[1]
FEPROM (Flash Erasable Programmable Read Only Memory)	Flash Erasable Programmable Read Only Memory[1]	FEPROM[1]
FF (Flexible Fuel)	Flexible Fuel[1]	FF[1]
FI (Fuel Injection)	Central Multiport Fuel Injection[1]	Central MFI[1]
FI (Fuel Injection)	Continuous Fuel Injection[1]	CFI[1]
FI (Fuel Injection)	Direct Fuel Injection[1]	DFI[1]
FI (Fuel Injection)	Indirect Fuel Injection[1]	IFI[1]
FI (Fuel Injection)	Multiport Fuel Injection[1]	MFI[1]
FI (Fuel Injection)	Sequential Multiport Fuel Injection[1]	SFI[1]
FI (Fuel Injection)	Throttle Body Fuel Injection[1]	TBI[1]
Flame Ionization Detector	Flame Ionization Detector	FID
Flash EEPROM (Electrically Erasable Programmable Read Only Memory)	Flash Electrically Erasable Programmable Read Only Memory[1]	FEEPROM[1]
Flash EPROM (Erasable Programmable Read Only Memory)	Flash Erasable Programmable Read Only Memory[1]	FEPROM[1]
Flexible Fuel	Flexible Fuel[1]	FF[1]
Flexible Fuel Sensor	Flexible Fuel Sensor[1]	FF Sensor
Fourth Gear	Fourth Gear	4GR
FP (Fuel Pump)	Fuel Pump	FP
FP (Fuel Pump) Module	Fuel Pump Module	FP Module
Freeze Frame	Freeze Frame	See Table 4
Front Wheel Drive	Front Wheel Drive	FWD
FRZF (Freeze Frame)	Freeze Frame	See Table 4
FT (Fuel Trim)	Fuel Trim[1]	FT[1]
Fuel Charging Station	Throttle Body[1]	TB[1]
Fuel Concentration Sensor	Flexible Fuel Sensor[1]	FF Sensor[1]
Fuel Injection	Central Multiport Fuel Injection[1]	Central MFI[1]
Fuel Injection	Continuous Fuel Injection[1]	CFI[1]
Fuel Injection	Direct Fuel Injection[1]	DFI[1]
Fuel Injection	Indirect Fuel Injection[1]	IFI[1]
Fuel Injection	Multiport Fuel Injection[1]	MFI[1]
Fuel Injection	Sequential Multiport Fuel Injection[1]	SFI[1]
Fuel Injection	Throttle Body Fuel Injection[1]	TBI[1]
Fuel Level Sensor	Fuel Level Sensor	Fuel Level Sensor
Fuel Module	Fuel Pump Module	FP Module
Fuel Pressure	Fuel Pressure[1]	Fuel Pressure[1]
Fuel Pressure	Fuel Pressure	See Table 4
Fuel Pressure Regulator	Fuel Pressure Regulator[1]	Fuel Pressure Regulator[1]
Fuel Pump	Fuel Pump	FP
Fuel Pump Relay	Fuel Pump Relay	FP Relay
Fuel Quality Sensor	Flexible Fuel Sensor[1]	FF Sensor[1]
Fuel Regulator	Fuel Pressure Regulator[1]	Fuel Pressure Regulator[1]
Fuel Sender	Fuel Pump Module	FP Module
Fuel Sensor	Fuel Level Sensor	Fuel Level Sensor
Fuel System Status	Fuel System Status	See Table 4
FUEL SYS	Fuel System Status	See Table 4
Fuel Tank Unit	Fuel Pump Module	FP Module
Fuel Trim	Fuel Trim[1]	FT[1]
Full Time Four Wheel Drive	Full Time Four Wheel Drive	FFWD
Full Throttle	Wide Open Throttle[1]	WOT[1]
FWD	Front Wheel Drive	FWD
GCM (Governor Control Module)	Governor Control Module	GCM
GEM (Governor Electronic Module)	Governor Control Module	GCM
GEN (Generator)	Generator	GEN
Generator	Generator	GEN
Glow Plug	Glow Plug[1]	Glow Plug[1]
GND (Ground)	Ground	GND
Governor	Governor	Governor
Governor Control Module	Governor Control Module	GCM
Governor Electronic Module	Governor Control Module	GCM
Green Per Mile	Green Per Mile	GPM
GRD (Ground)	Ground	GND
Ground	Ground	GND
Heated Oxygen Sensor	Heated Oxygen Sensor[1]	HO2S[1]
HEDF (High Electric Drive Fan) Control	Fan Control	EC
HEGO (Heated Exhaust Gas Oxygen) Sensor	Heated Oxygen Sensor[1]	HO2S[1]
HEI (High Energy Ignition)	Distributor Ignition[1]	DI[1]
High Speed FC (Fan Control) Switch	High Speed Fan Control Switch	High Speed EC Switch
HO2S (Heated Oxygen Sensor)	Heated Oxygen Sensor[1]	HO2S[1]
HOS (Heated Oxygen Sensor)	Heated Oxygen Sensor[1]	HO2S[1]
Hot Wire Anemometer	Mass Air Flow Sensor[1]	MAF Sensor[1]
IA (Intake Air)	Intake Air	IA
IA (Intake Air) Duct	Intake Air Duct	IA Duct
IAC (Idle Air Control)	Idle Air Control[1]	IAC[1]
IAC (Idle Air Control) Thermal Valve	Idle Air Control Thermal Valve[1]	IAC Thermal Valve[1]
IAC (Idle Air Control) Valve	Idle Air Control Valve[1]	IAC Valve[1]
IACV (Idle Air Control Valve)	Idle Air Control Valve[1]	IAC Valve[1]
IAT (Intake Air Temperature)	Intake Air Temperature[1]	IAT[1]
IAT (Intake Air Temperature) Sensor	Intake Air Temperature Sensor[1]	IAT Sensor[1]
IATS (Intake Air Temperature Sensor)	Intake Air Temperature Sensor[1]	IAT Sensor[1]
IC (Ignition Control)	Ignition Control[1]	IC[1]

TABLE 1—CROSS REFERENCE AND LOOK UP (CONTINUED)

Existing Usage	Acceptable Usage	Acceptable Accredited Usage
ICMs (Ignition Control Module)	Ignition Control Module[1]	ICM[1]
ICP (Injection Control Pressure)	Injection Control Pressure[1]	ICP[1]
IDFI (Indirect Fuel Injection)	Indirect Fuel Injection[1]	IDFI[1]
IDI (Integrated Direct Ignition)	Electronic Ignition[1]	IDI[1]
IDI (Indirect Diesel Injection)	Indirect Fuel Injection[1]	IDI[1]
Idle Air Bypass Control	Idle Air Control[1]	IAC[1]
Idle Air Control	Idle Air Control[1]	IAC[1]
Idle Air Control Valve	Idle Air Control Valve[1]	IAC Valve[1]
Idle Speed Control	Idle Air Control[1]	IAC[1]
Idle Speed Control	Idle Speed Control[1]	ISC[1]
Idle Speed Control Actuator	Idle Speed Control Actuator[1]	ISC Actuator[1]
IFI (Indirect Fuel Injection)	Indirect Fuel Injection[1]	IDI[1]
IFS (Inertia Fuel Shutoff)	Inertia Fuel Shutoff	IFS
Ignition Control	Ignition Control[1]	ICM[1]
Ignition Control Module	Ignition Control Module[1]	ICM[1]
I/M (Inspection and Maintenance)	Inspection and Maintenance	I/M
IMRC (Intake Manifold Runner Control)	Intake Manifold Runner Control	IMRC
In Tank Module	Fuel Pump Module	FP Module
Indirect Fuel Injection	Indirect Fuel Injection[1]	IDI[1]
Inertia Fuel Shutoff	Inertia Fuel Shutoff	IFS
Inertia Fuel - Shutoff Switch	Inertia Fuel Shutoff Switch	IFS Switch
Inertia Switch	Inertia Fuel Shutoff Switch	IFS Switch
Injection Control Pressure	Injection Control Pressure[1]	ICP[1]
Input Shaft Speed	Input Shaft Speed	ISS
INT (Integrator)	Short Term Fuel Trim[1]	Short Term FT[1]
Inspection and Maintenance	Inspection and Maintenance	I/M
Intake Air	Intake Air	IA
Intake Air Duct	Intake Air Duct	IA Duct
Intake Air Temperature	Intake Air Temperature[1]	IAT[1]
Intake Air Temperature Sensor	Intake Air Temperature Sensor[1]	IAT Sensor[1]
Intake Manifold Absolute Pressure Sensor	Manifold Absolute Pressure Sensor[1]	MAP Sensor[1]
Intake Manifold Runner Control	Intake Manifold Runner Control	IMRC
Integrated Relay Module	Relay Module	RM
Integrator	Short Term Fuel Trim[1]	Short Term FT[1]
Inter Cooler	Charge Air Cooler[1]	CAC[1]
ISC (Idle Speed Control)	Idle Air Control[1]	IAC[1]
ISC (Idle Speed Control)	Idle Speed Control[1]	ISC[1]
ISC (Idle Speed Control) Actuator	Idle Speed Control Actuator[1]	ISC Actuator[1]
ISC BPA (Idle Speed Control By Pass Air)	Idle Air Control[1]	IAC[1]
ISC (Idle Speed Control) Solenoid Vacuum Valve	Idle Speed Control Solenoid Vacuum Valve[1]	ISC Solenoid Vacuum Valve[1]
ISS (Input Shaft Speed)	Input Shaft Speed	ISS
K-Jetronic	Continuous Fuel Injection[1]	CFI[1]
KAM (Keep Alive Memory)	Non Volatile Random Access Memory[1]	NVRAM[1]
KAM (Keep Alive Memory)	Keep Alive Random Access Memory[1]	Keep Alive RAM[1]
KE-Jetronic	Continuous Fuel Injection[1]	CFI[1]
KE-Motronic	Continuous Fuel Injection[1]	CFI[1]
Knock Sensor	Knock Sensor[1]	KS[1]
KS (Knock Sensor)	Knock Sensor[1]	KS[1]
L-Jetronic	Multiport Fuel Injection[1]	MFI[1]
Lambda	Oxygen Sensor[1]	O2S[1]
LH-Jetronic	Multiport Fuel Injection[1]	MFI[1]
Light Off Catalyst	Warm Up Three Way Catalytic Converter[1]	WU-TWC[1]
Light Off Catalyst	Warm Up Oxidation Catalytic Converter[1]	WU-OC[1]
Line Pressure Control Solenoid Valve	Line Pressure Control Solenoid Valve	Line PC Solenoid Valve
LO/AD (Calendared Load Value)	Calendared Load Value	LOAD
Lock Up Relay	Torque Converter Clutch Relay[1]	TCC Relay[1]
Long Term FT (Fuel Trim)	Long Term Fuel Trim[1]	Long Term FT[1]
Long Term Fuel Trim	Long Term FT	Long Term FT
LONG FT	Long Term Fuel Trim	See Table 4
Low Speed FC (Fan Control) Switch	Low Speed Fan Control Switch	Low Speed FC Switch
LUS (Lock Up Solenoid) Valve	Torque Converter Clutch Solenoid Valve[1]	TCC Solenoid Valve[1]
MC (Mixture Control)	Mixture Control[1]	MC[1]
MAF (Mass Air Flow)	Mass Air Flow[1]	MAF[1]
MAF (Mass Air Flow) Sensor	Mass Air Flow Sensor[1]	MAF Sensor[1]
Malfunction Indicator Lamp	Malfunction Indicator Lamp[1]	MIL[1]
Manifold Absolute Pressure	Manifold Absolute Pressure[1]	MAP[1]
Manifold Absolute Pressure Sensor	Manifold Absolute Pressure Sensor[1]	MAP Sensor[1]
Manifold Differential Pressure	Manifold Differential Pressure[1]	MDP[1]
Manifold Surface Temperature	Manifold Surface Temperature[1]	MST[1]
Manifold Vacuum Zone	Manifold Vacuum Zone[1]	MVZ[1]
Manual Lever Position Sensor	Transmission Range Sensor[1]	TR Sensor[1]
MAP (Manifold Absolute Pressure)	Manifold Absolute Pressure[1]	MAP[1]
MAP (Manifold Absolute Pressure) Sensor	Manifold Absolute Pressure Sensor[1]	MAP Sensor[1]
MAPS (Manifold Absolute Pressure Sensor)	Manifold Absolute Pressure Sensor[1]	MAP Sensor[1]
Mass Air Flow	Mass Air Flow[1]	MAF[1]
Mass Air Flow Sensor	Mass Air Flow Sensor[1]	MAF Sensor[1]
MAT (Manifold Air Temperature)	Intake Air Temperature[1]	IAT[1]
MATS (Manifold Air Temperature Sensor)	Intake Air Temperature Sensor[1]	IAT Sensor[1]
MC (Mixture Control)	Mixture Control[1]	MC[1]
MCS (Mixture Control Solenoid)	Mixture Control Solenoid[1]	MC Solenoid[1]
MCU (Microprocessor Control Unit)	Powertrain Control Module[1]	PCM[1]
MDP (Manifold Differential Pressure)	Manifold Differential Pressure[1]	MDP[1]

TABLE 1---CROSS REFERENCE AND LOOK UP (CONTINUED)

Existing Usage	Acceptable Usage	Acceptable Acronized Usage
MFI (Multiport Fuel Injection)	Multiport Fuel Injection[1]	MFI[1]
MIL (Malfunction Indicator Lamp)	Malfunction Indicator Lamp[1]	MIL[1]
Mixture Control	Mixture Control[1]	MC[1]
MLPS (Manual Lever Position Sensor)	Transmission Range Sensor[1]	TR Sensor[1]
Modes	Diagnostic Test Mode[1]	DTM[1]
Mono-Jetronic	Throttle Body Injection[1]	TBI[1]
Mono-Motronic	Throttle Body Injection[1]	TBI[1]
Monotronic	Throttle Body Fuel Injection[1]	TBI[1]
Motronic-Pressure	Multiport Fuel Injection[1]	MFI[1]
Motronic	Multiport Fuel Injection[1]	MFI[1]
MPI (Multipoint Injection)	Multiport Fuel Injection[1]	MFI[1]
MPI (Multiport Injection)	Multiport Fuel Injection[1]	MFI[1]
MRPS (Manual Range Position Switch)	Transmission Range Switch	TR Switch
MST (Manifold Surface Temperature)	Manifold Surface Temperature[1]	MST[1]
Multiport Fuel Injection	Multiport Fuel Injection[1]	MFI[1]
MVZ (Manifold Vacuum Zone)	Manifold Vacuum Zone[1]	MVZ[1]
NDS (Neutral Drive Switch)	Park/Neutral Position Switch[1]	PNP Switch[1]
Neutral Safety Switch	Park/Neutral Position Switch[1]	PNP Switch[1]
NGS (Neutral Gear Switch)	Park/Neutral Position Switch[1]	PNP Switch[1]
Non Dispersive Infrared	Non Dispersive Infrared	NDIR
Non Volatile Random Access Memory	Non Volatile Random Access Memory[1]	NVRAM[1]
NPS (Neutral Position Switch)	Park/Neutral Position Switch[1]	PNP Switch[1]
NVM (Non Volatile Memory)	Non Volatile Random Access Memory[1]	NVRAM[1]
NVRAM (Non Volatile Random Access Memory)	Non Volatile Random Access Memory[1]	NVRAM[1]
O2 (Oxygen) Sensor	Oxygen Sensor[1]	O2S[1]
O2S (Oxygen Sensor)	Oxygen Sensor[1]	O2S[1]
Oxygen Sensor Location	Oxygen Sensor Location	See Table 4
OBD (On Board Diagnostic)	On Board Diagnostic[1]	OBD[1]
OBD Status	OBD Status	see Table 4
OBD STAT	OBD Status	see Table 4
OC (Oxidation Catalyst)	Oxidation Catalytic Converter[1]	OC[1]
Oil Pressure Sender	Engine Oil Pressure Sensor	EOP Sensor
Oil Pressure Sensor	Engine Oil Pressure Sensor	EOP Sensor
Oil Pressure Switch	Engine Oil Pressure Switch	EOP Switch
OL (Open Loop)	Open Loop[1]	OL[1]
On Board Diagnostic	On Board Diagnostic[1]	OBD[1]
Open Loop	Open Loop[1]	OL[1]
OS (Oxygen Sensor)	Oxygen Sensor[1]	O2S[1]
OSS (Output Shaft Speed) Sensor	Output Shaft Speed Sensor[1]	OSS Sensor[1]
Output Driver	Driver	Driver
Output Shaft Speed Sensor	Output Shaft Speed Sensor[1]	OSS Sensor[1]
Oxidation Catalytic Converter	Oxidation Catalytic Converter[1]	OC[1]
OXS (Oxygen Sensor) Indicator	Service Reminder Indicator[1]	SRI[1]
Oxygen Sensor	Oxygen Sensor[1]	O2S[1]
P/N (Park/Neutral)	Park/Neutral Position[1]	PNP[1]
P/S (Power Steering) Pressure Switch	Power Steering Pressure Switch	PSP Switch
P- (Pressure) Sensor	Manifold Absolute Pressure Sensor[1]	MAP Sensor[1]
PAIR (Pulsed Secondary Air Injection)	Pulsed Secondary Air Injection[1]	PAIR[1]
Parameter Identification	Parameter Identification	PID
Parameter Identification Supported	Parameter Identification Supported	See Table 6
Park/Neutral Position	Park/Neutral Position[1]	PNP[1]
PC (Pressure Control) Solenoid Valve	Pressure Control Solenoid Valve[1]	PC Solenoid Valve[1]
PCM (Powertrain Control Module)	Powertrain Control Module[1]	PCM[1]
PCV (Positive Crankcase Ventilation)	Positive Crankcase Ventilation[1]	PCV[1]
PCV (Positive Crankcase Ventilation) Valve	Positive Crankcase Ventilation Valve[1]	PCV Valve[1]
Percent Alcohol Sensor	Flexible Fuel Sensor[1]	FF Sensor[1]
Periodic Trap Oxidizer	Periodic Trap Oxidizer[1]	PTOX[1]
PFE (Pressure Feedback Exhaust Gas Recirculation Sensor	Feedback Pressure Exhaust Gas Recirculation Sensor[1]	Feedback Pressure EGR Sensor[1]
PFI (Port Fuel Injection)	Multiport Fuel Injection[1]	MFI[1]
PG (Pulse Generator)	Vehicle Speed Sensor[1]	VSS[1]
PGM-FI (Programmed Fuel Injection)	Multiport Fuel Injection[1]	MFI[1]
PID (Parameter Identification)	Parameter Identification	PID
PID SUP	Parameter Identification Supported	See Table 6
PIP (Position Indicator Pulse)	Crankshaft Position[1]	CKP[1]
PNP (Park/Neutral Position)	Park/Neutral Position[1]	PNP[1]
Positive Crankcase Ventilation	Positive Crankcase Ventilation[1]	PCV[1]
Positive Crankcase Ventilation Valve	Positive Crankcase Ventilation Valve[1]	PCV Valve[1]
Power Steering Pressure	Power Steering Pressure	PSP
Power Steering Pressure Switch	Power Steering Pressure Switch	PSP Switch
Powertrain Control Module	Powertrain Control Module[1]	PCM[1]
Pressure Control Solenoid Valve	Pressure Control Solenoid Valve[1]	PC Solenoid Valve[1]
Pressure Feedback EGR (Exhaust Gas Recirculation)	Feedback Pressure Exhaust Gas Recirculation[1]	Feedback Pressure EGR[1]
Pressure Sensor	Manifold Absolute Pressure Sensor[1]	MAP Sensor[1]
Pressure Feedback EGR (Exhaust Gas Recirculation) System	Feedback Pressure Exhaust Gas Recirculation System[1]	Feedback Pressure EGR System[1]
Pressure Transducer EGR (Exhaust Gas Recirculation) System	Pressure Transducer Exhaust Gas Recirculation System[1]	Pressure Transducer EGR System[1]
PRNDL (Park- Reverse- Neutral- Drive- Low)	Transmission Range	TR
Programmable Read Only Memory	Programmable Read Only Memory[1]	PROM[1]
PROM (Programmable Read Only Memory)	Programmable Read Only Memory[1]	PROM[1]
PSP (Power Steering Pressure)	Power Steering Pressure	PSP

TABLE 1--CROSS REFERENCE AND LOOK UP (CONTINUED)

Existing Usage	Acceptable Usage	Acceptable Acronym/ Usage
PSF (Power Steering Pressure) Switch	Power Steering Pressure Switch	PSP Switch
PSPS (Power Steering Pressure Switch)	Power Steering Pressure Switch	PSP Switch
PTOX (Periodic Trap Oxidizer)	Periodic Trap Oxidizer[1]	PTOX[1]
Pulsair	Pulsed Secondary Air Injection[1]	PAIR[1]
Pulsed Secondary Air Injection	Pulsed Secondary Air Injection[1]	PAIR[1]
Pulse Width Modulation	Pulse Width Modulation	PWM
PWM	Pulse Width Modulation	PWM
QDM (Quad Driver Module)	Relay	Relay
Quad Driver Module	Relay	Relay
Radiator Fan Control	Fan Control	FC
Radiator Fan Relay	Fan Control Relay	FC Relay
RAM (Random Access Memory)	Random Access Memory[1]	RAM[1]
Random Access Memory	Random Access Memory[1]	RAM[1]
Read Only Memory	Read Only Memory[1]	ROM[1]
Rear Wheel Drive	Rear Wheel Drive	RWD
Recirculated Exhaust Gas Temperature Sensor	Exhaust Gas Recirculation Temperature Sensor	EGRT Sensor[1]
Reed Valve	Pulsed Secondary Air Injection Valve[1]	PAIR Valve[1]
REGTS (Recirculated Exhaust Gas Temperature Sensor)	Exhaust Gas Recirculation Temperature Sensor[1]	EGRT Sensor[1]
Relay Module	Relay Module	RM
Remote Mount TPI (Thick Film Ignition)	Distributor Ignition[1]	DI[1]
Revolutions per Minute	Engine Speed[1]	RPM[1]
RM (Relay Module)	Relay Module	RM
ROM (Read Only Memory)	Read Only Memory[1]	ROM[1]
RPM (Revolutions per Minute)	Engine Speed[1]	RPM[1]
RWD	Rear Wheel Drive	RWD
S4WD	Selectable Four Wheel Drive	S4WD
SABV (Secondary Air Bypass Valve)	Secondary Air Injection Bypass Valve[1]	AIB Bypass Valve[1]
SACV (Secondary Air Check Valve)	Secondary Air Injection Control Valve[1]	AIB Control Valve[1]
SASV (Secondary Air Switching Valve)	Secondary Air Injection Switching Valve[1]	AIB Switching Valve[1]
SBEC (Single Board Engine Control)	Powertrain Control Module[1]	PCM[1]
SBS (Supercharger Bypass Solenoid)	Supercharger Bypass Solenoid[1]	SCB Solenoid[1]
SC (Supercharger)	Supercharger[1]	SC[1]
Scan Tool	Scan Tool[1]	ST[1]
SCB (Supercharger Bypass)	Supercharger Bypass[1]	SCB[1]
Secondary Air Bypass Valve	Secondary Air Injection Bypass Valve[1]	AIB Bypass Valve[1]
Secondary Air Check Valve	Secondary Air Injection Check Valve[1]	AIB Check Valve[1]
Secondary Air Injection	Secondary Air Injection[1]	AIB[1]
Secondary Air Injection Bypass	Secondary Air Injection Bypass[1]	AIB Bypass[1]
Secondary Air Injection Diverter	Secondary Air Injection Diverter[1]	AIB Diverter[1]
Secondary Air Switching Valve	Secondary Air Injection Switching Valve[1]	AIB Switching Valve[1]
Selectable Four Wheel Drive	Selectable Four Wheel Drive	S4WD
SEFI (Sequential Electronic Fuel Injection)	Sequential Multiport Fuel Injection[1]	SFI[1]
Self Test	On Board Diagnostic[1]	OBD[1]
Self Test Codes	Electronic Trouble Code[1]	ETC[1]
Self Test Connector	Data Link Connector[1]	DLC[1]
Sequential Multiport Fuel Injection	Sequential Multiport Fuel Injection[1]	SFI[1]
Service Engine Soon	Service Reminder Indicator[1]	SRI[1]
Service Engine Soon	Malfunction Indicator Lamp[1]	MIL[1]
Service Reminder Indicator	Service Reminder Indicator[1]	SRI[1]
SFI (Sequential Fuel Injection)	Sequential Multiport Fuel Injection[1]	SFI[1]
Shift Solenoid	Shift Solenoid[1]	SS[1]
SIMR Solenoid Valve	Shift Solenoid Valve[1]	SS Valve[1]
Short Term FT (Fuel Trim)	Short Term Fuel Trim[1]	Short Term FT[1]
Short Term Fuel Trim	Short Term Fuel Trim[1]	Short Term FT[1]
SMRT FT	Short Term Fuel Trim[1]	See Table 4
SLP (Selection Lever Position)	Transmission Range	TR
SMEC (Single Module Engine Control)	Powertrain Control Module[1]	PCM[1]
Smoke Puff Limiter	Smoke Puff Limiter[1]	SPL[1]
SPARK ADV	Spark Advance	See Table 4
Spark Advance	Spark Advance	See Table 4
Spark Plug	Spark Plug[1]	Spark Plug[1]
SPI (Single Point Injection)	Throttle Body Fuel Injection[1]	TBI[1]
SPL (Smoke Puff Limiter)	Smoke Puff Limiter[1]	SPL[1]
SS (Shift Solenoid)	Shift Solenoid[1]	SS[1]
SRI (Service Reminder Indicator)	Service Reminder Indicator[1]	SRI[1]
SRT (System Readiness Test)	System Readiness Test[1]	SRT[1]
ST (Scan Tool)	Scan Tool[1]	ST[1]
Supercharger	Supercharger[1]	SC[1]
Supercharger Bypass	Supercharger Bypass[1]	SCB[1]
Sync Pickup	Camshaft Position[1]	CMP[1]
System Readiness Test	System Readiness Test[1]	SRT[1]
3-2TS (3-2 Timing Solenoid)	3-2 Timing Solenoid	3-2TS
3-2TS Valve (3-2 Timing Solenoid) Valve	3-2 Timing Solenoid Valve	3-2TS Valve
3-2 Timing Solenoid	3-2 Timing Solenoid	3-2TS
3-2 Timing Solenoid Valve	3-2 Timing Solenoid Valve	3-2TS Valve
3GR (Third Gear)	Third Gear	3GR
TAB (Thermactor Air Bypass)	Secondary Air Injection Bypass[1]	AIB Bypass[1]
TAC (Throttle Actuator Control)	Throttle Actuator Control	TAC
TAC (Throttle Actuator Control) Module	Throttle Actuator Control Module[1]	TAC Module[1]
TAD (Thermactor Air Diverter)	Secondary Air Injection Diverter[1]	AIB Diverter[1]
TB (Throttle Body)	Throttle Body[1]	TB[1]
TBI (Throttle Body Fuel Injection)	Throttle Body Fuel Injection[1]	TBI[1]

TABLE 1—CROSS REFERENCE AND LOOK UP (CONTINUED)

Existing Usage	Acceptable Usage	Acceptable Approved Usage
TBT (Throttle Body Temperature)	Intake Air Temperature[1]	IAT[1]
TC (Turbocharger)	Turbocharger[1]	TC[1]
TC (Turbocharger) Wastegate	Turbocharger Wastegate[1]	TC Wastegate[1]
TC (Turbocharger) Wastegate Regulating Valve	Turbocharger Wastegate Regulating Valve[1]	TC Wastegate Regulating Valve[1]
TCC (Torque Converter Clutch)	Torque Converter Clutch[1]	TCC[1]
TCC (Torque Converter Clutch) Relay	Torque Converter Clutch Relay[1]	TCC Relay[1]
TCC (Torque Converter Clutch) Solenoid	Torque Converter Clutch Solenoid[1]	TCC Solenoid[1]
TCC (Torque Converter Clutch) Solenoid Valve	Torque Converter Clutch Solenoid Valve[1]	TCC Solenoid Valve[1]
TCM (Transmission Control Module)	Transmission Control Module	TCM
TCCP (Torque Converter Clutch Pressure)	Torque Converter Clutch Pressure	TCCP
TFI (Thick Film Ignition)	Distributor Ignition[1]	DI[1]
TFI (Thick Film Ignition) Module	Ignition Control Module[1]	ICM[1]
TFP (Transmission Fluid Pressure)	Transmission Fluid Pressure	TFP
TFT (Transmission Fluid Temperature) Sensor	Transmission Fluid Temperature Sensor	TFT Sensor
Thermac	Secondary Air Injection[1]	AIR[1]
Thermac Air Cleaner	Air Cleaner[1]	ACL[1]
Thermactor	Secondary Air Injection[1]	AIR[1]
Thermactor Air Bypass	Secondary Air Injection Bypass[1]	AIR Bypass[1]
Thermactor Air Diverter	Secondary Air Injection Diverter[1]	AIR Diverter[1]
Thermactor II	Pulsed Secondary Air Injection[1]	PAIR[1]
Thermal Vacuum Switch	Thermal Vacuum Valve[1]	TVV[1]
Thermal Vacuum Valve	Thermal Vacuum Valve[1]	TVV[1]
Third Gear	Third Gear	3RD
Three Way + Oxidation Catalytic Converter	Three Way + Oxidation Catalytic Converter[1]	TWC+OC[1]
Three Way Catalytic Converter	Three Way Catalytic Converter[1]	TWC[1]
Throttle Actuator Control	Throttle Actuator Control	TAC
Throttle Actuator Control Module	Throttle Actuator Control Module	TAC Module
Throttle Body	Throttle Body[1]	TB[1]
Throttle Body Fuel Injection	Throttle Body Fuel Injection[1]	TBI[1]
Throttle Opener	Idle Speed Control[1]	ISC[1]
Throttle Opener Vacuum Switching Valve	Idle Speed Control Solenoid Vacuum Valve[1]	ISC Solenoid Vacuum Valve[1]
Throttle Opener VSV (Vacuum Switching Valve)	Idle Speed Control Solenoid Vacuum Valve[1]	ISC Solenoid Vacuum Valve[1]
Throttle Position	Throttle Position[1]	TP
Throttle Position Sensor	Throttle Position Sensor[1]	TP Sensor[1]
Throttle Position Switch	Throttle Position Switch[1]	TP Switch[1]
Throttle Potentiometer	Throttle Position Sensor[1]	TP Sensor[1]
TOC (Trap Oxidizer - Continuous)	Continuous Trap Oxidizer[1]	CTOX[1]
TOP (Trap Oxidizer - Periodic)	Periodic Trap Oxidizer[1]	PTOX[1]
Torque Converter Clutch	Torque Converter Clutch[1]	TCC[1]
Torque Converter Clutch Pressure	Torque Converter Clutch Pressure	TCCP
Torque Converter Clutch Relay	Torque Converter Clutch Relay[1]	TCC Relay[1]
Torque Converter Clutch Solenoid	Torque Converter Clutch Solenoid[1]	TCC Solenoid[1]
Torque Converter Clutch Solenoid Valve	Torque Converter Clutch Solenoid Valve[1]	TCC Solenoid Valve[1]
TP (Throttle Position)	Throttle Position[1]	TP[1]
TP (Throttle Position) Sensor	Throttle Position Sensor[1]	TP Sensor[1]
TP (Throttle Position) Switch	Throttle Position Switch[1]	TP Switch[1]
TPI (Tuned Port Injection)	Multiport Fuel Injection[1]	MFI[1]
TPNP (Transmission Park Neutral Position)	Park/Neutral Position[1]	PNP[1]
TPS (Throttle Position Sensor)	Throttle Position Sensor[1]	TP Sensor[1]
TPS (Throttle Position Switch)	Throttle Position Switch[1]	TP Switch[1]
TR (Transmission Range)	Transmission Range	TR
Track Road Load Horsepower	Track Road Load Horsepower	TRLHP
Transmission Control Module	Transmission Control Module	TCM
Transmission Fluid Pressure	Transmission Fluid Pressure	TFP
Transmission Fluid Temperature Sensor	Transmission Fluid Temperature Sensor	TFT Sensor
Transmission Park Neutral Position	Park/Neutral Position[1]	PNP[1]
Transmission Position Switch	Transmission Range Switch	TR Switch
Transmission Range Selector	Transmission Range	TR
Transmission Range Sensor	Transmission Range Sensor	TR Sensor
TRS (Transmission Range Selector)	Transmission Range	TR
TRSS (Transmission Range Selection Switch)	Transmission Range Switch	TR Switch
TSS (Turbine Shaft Speed) Sensor	Turbine Shaft Speed Sensor[1]	TSS Sensor[1]
Tuned Port Injection	Multiport Fuel Injection[1]	MFI[1]
Turbine Shaft Speed Sensor	Turbine Shaft Speed Sensor[1]	TSS Sensor[1]
Turbo (Turbocharger)	Turbocharger[1]	TC[1]
Turbocharger	Turbocharger[1]	TC[1]
Turbocharger Wastegate	Turbocharger Wastegate[1]	TC Wastegate[1]
Turbocharger Wastegate Regulating Valve	Turbocharger Wastegate Regulating Valve[1]	TC Wastegate Regulating Valve[1]
TVS (Thermal Vacuum Switch)	Thermal Vacuum Valve[1]	TVV[1]
TVV (Thermal Vacuum Valve)	Thermal Vacuum Valve[1]	TVV[1]
TWC (Three Way Catalytic Converter)	Three Way Catalytic Converter[1]	TWC[1]
TWC + OC (Three Way + Oxidation Catalytic Converter)	Three Way + Oxidation Catalytic Converter[1]	TWC+OC[1]
VAC (Vacuum) Sensor	Manifold Differential Pressure Sensor[1]	MDP Sensor[1]
Vacuum Switches	Manifold Vacuum Zone Switch	MVZ Switch[1]
VAF (Volume Air Flow)	Volume Air Flow[1]	VAF[1]
Valve Position EGR (Exhaust Gas Recirculation) System	Valve Position Exhaust Gas Recirculation System[1]	Valve Position EGR System[1]
Vane Air Flow	Volume Air Flow[1]	VAF[1]
Variable Control Relay Module	Variable Control Relay Module	VCRM
Variable Fuel Sensor	Flexible Fuel Sensor	FF Sensor[1]
VAT (Vane Air Temperature)	Intake Air Temperature[1]	IAT[1]
VCC (Viscous Converter Clutch)	Torque Converter Clutch[1]	TCC[1]

TABLE 1—CROSS REFERENCE AND LOOK UP (CONTINUED)

Existing Usage	Acceptable Usage	Acceptable Abbreviated Usage
VCM	Vehicle Control Module	VCM
VCRM	Vehicle Control Relay Module	VCRM
Vehicle Control Module	Vehicle Control Module	VCM
Vehicle Identification Number	Vehicle Identification Number	VIN
Vehicle Speed Sensor	Vehicle Speed Sensor[1]	VSS[1]
VIN (Vehicle Identification Number)	Vehicle Identification Number	VIN
VIP (Vehicle In Process) Connector	Data Link Connector[1]	DLC[1]
Vacuum Converter Clutch	Torque Converter Clutch[1]	TCC[1]
Voltage Regulator	Voltage Regulator	VR
Volume Air Flow	Volume Air Flow[1]	VAF[1]
VR (Voltage Regulator)	Voltage Regulator	VR
VSS (Vehicle Speed Sensor)	Vehicle Speed Sensor[1]	VSS[1]
VSV (Vacuum Solenoid Valve) (Canister)	Evaporative Emission Canister Purge Valve[1]	EVAP Canister Purge Valve[1]
VSV (Vacuum Solenoid Valve) (EVAP)	Evaporative Emission Canister Purge Valve[1]	EVAP Canister Purge Valve[1]
VSV (Vacuum Solenoid Valve) (Throttle)	Idle Speed Control Solenoid Vacuum Valve[1]	ISC Solenoid Vacuum Valve[1]
Warm Up Oxidation Catalytic Converter	Warm Up Oxidation Catalytic Converter[1]	WU-OC[1]
Warm Up Three Way Catalytic Converter	Warm Up Three Way Catalytic Converter[1]	WU-OC[1]
Wide Open Throttle	Wide Open Throttle[1]	WOT[1]
WOT (Wide Open Throttle)	Wide Open Throttle[1]	WOT[1]
WOTS (Wide Open Throttle Switch)	Wide Open Throttle Switch[1]	WOT Switch[1]
WU-OC (Warm Up Oxidation Catalytic Converter)	Warm Up Oxidation Catalytic Converter[1]	WU-OC[1]
WU-TWC (Warm Up Three Way Catalytic Converter)	Warm Up Three Way Catalytic Converter[1]	WU-TWC[1]

Recommended Terms and Recommended Acronyms See Table 2

[1] Emission-Related Term

Bold indicates new/revised entry

6. *Recommended Terms*—Table 2 is an alphabetical listing of modifiers to be used in combination with base words

TABLE 2—RECOMMENDED TERMS

Recommended Term	Acronym	Definition
3-2 Timing Solenoid	3-2TS	A device that controls the "third to second" timing valve.
Accelerator Pedal	APP[2]	See Glossary Entry "ACCELERATOR PEDAL."
Accelerator Pedal Position[1]	APP	See Glossary Entry "ACCELERATOR PEDAL."
Air Cleaner[1]	ACL	See Glossary Entry "CLEANER."
Air Conditioning	A/C	See Glossary Entry "AIR CONDITIONING."
Ambient Air Temperature	AAT	Air Temperature Surrounding the vehicle.
Automatic Transaxle	A/T	See Glossary Entry "TRANSAXLE."
Automatic Transmission	A/T	See Glossary Entry "TRANSMISSION."
Barometric Pressure[1]	BARO[2]	See Glossary Entry "PRESSURE."
Battery Positive Voltage	B+[2]	See Glossary Entry "BATTERY."
Brake Pedal Position[1]	BPP	See Glossary Entry "BRAKE."
Brake Pressure	—	Positive Pressure in the brake system.
Calculated Load Value	LOAD	Percent of engine capacity being used.
Camshaft Position[1]	CMP	See Glossary Entry "CAMSHAFT."
Canister[1]	—	See Glossary Entry "CANISTER."
Carburetor[1]	CARB[2]	See Glossary Entry "CARBURETOR."
Catalytic Converter Heater[1]	—	A device to quickly heat a Catalytic Converter.
Charge Air Cooler[1]	CAC[2]	A device which lowers the temperature of the pressurized intake air.
Closed Loop[1]	CL	See Glossary Entry "CLOSED LOOP."
Closed Throttle Position[1]	CTP	See Glossary Entry "THROTTLE."
Clutch Pedal Position[1]	CPP	See Glossary Entry "CLUTCH."
Coast Clutch Solenoid	CCS	A device that controls the Coast Clutch Valve.
Constant Volume Sampler	CVS	An exhaust sampling system which flows a constant amount of ambient air diluted exhaust.
Continuous Fuel Injection[1]	CFI	A fuel injection system with the injector flow controlled by fuel pressure
Continuous Trap Oxidizer[1]	CTOX	A system for lowering diesel engine particulates emissions by collecting exhaust particulates and continuously burning them through oxidation
Crankshaft Position[1]	CKP	See Glossary Entry "CRANKSHAFT."
Orifice Flow Venturi	OFV	An air flow regulating device which uses a specific wave to limit air flow
Data Link Connector[1]	DLC[2]	Connector providing access and/or control of the vehicle information, operating conditions, and diagnostic information.
Diagnostic Test Mode[1]	DTM	A level of diagnostic capability in an On Board Diagnostic (OBD) system. This may include different functional states to observe signals, a basic level to read diagnostic trouble codes, a manufacturer level which provides information on signal levels, bi-directional control with on/off board aids, and the ability to interface with remote diagnostic
Diagnostic Trouble Code[1]	DTC	An alpha/numeric identifier for a fault condition identified by the On-Board Diagnostic System
Direct Fuel Injection[1]	DFI	Fuel injection system that supplies fuel directly into the combustion chamber
Distributor Ignition[1]	DI	A system in which the ignition coil secondary circuit is switched by a distributor in proper sequence to various spark plugs.
Driver	—	See Glossary Entry "Driver."
Early Fuel Evaporation[1]	EFE	Enhancing airfloat vaporization during engine warm up.
EGR Temperature[1]	EGRT	Sensing EGR function based on temperature change. Primarily in systems with mechanical flow control devices.
Electrically Erasable Programmable Read Only Memory[1]	EEPROM	An electronic device named electrically erasable programmable read only memory.
Electronic Ignition[1]	EI	A system in which the ignition coil secondary circuit is dedicated to specific spark plugs without the use of a distributor.

TABLE 5--RECOMMENDED TERMS (CONTINUED)

Recommended Term	Acronym	Definition
Engine Control[1]	EC	See Glossary Entries "ENGINE" and "CONTROL."
Engine Control Module[1]	ECM[2]	See Glossary Entries "ENGINE," "CONTROL" and "MODULE."
Engine Coolant Level	ECL	See Glossary Entries "ENGINE," "COOLANT" and "LEVEL."
Engine Coolant Temperature[1]	ECT	See Glossary Entries "ENGINE" and "COOLANT."
Engine Modification[1]	EM	A method of lowering engine emissions through changes in basic engine construction or in fuel and spark calibration.
Engine Oil Pressure	EOP	Positive pressure in the engine's lubrication system.
Engine Oil Temperature	EOT	Temperature of engine lubricating oil.
Engine Speed[1]	RPM[2]	See Glossary Entries "ENGINE" and "SPEED."
Erasable Programmable Read Only Memory[1]	EPROM	An electronic device named erasable programmable read only memory.
Evaporative Emission[1]	EVAP[2]	A system used to prevent fuel vapor from escaping into the atmosphere. Typically includes a charcoal canister to store fuel vapors.
Exhaust Gas Recirculation[1]	EGR	Reducing NOx emissions levels by adding exhaust gas to the incoming air/fuel mixture.
Exhaust Pressure	EP	See glossary Entries "EXHAUST" and "PRESSURE."
Fan Control	FC	See Glossary Entries "FAN" and "CONTROL."
Flame Ionization Detector	FID	A device used to measure hydrocarbon concentrations.
Flash Electrically Erasable Programmable Read Only Memory[1]	FEEPROM	An electronic device named flash electrically erasable programmable read only memory.
Flash Erasable Programmable Read Only Memory[1]	FEPROM	An electronic device named flash erasable programmable read only memory.
Flexible Fuel[1]	FF	A system capable of using a variety of fuels for vehicle operation.
Fourth Gear	4GR[2]	Identifies the gear in which the transmission is operating in at a particular moment (e.g., the Transmission Range (TR) switch may indicate that "drive" was selected, but the transmission is operating in 4th gear as indicated by 4GR switch).
Freeze Frame	...[3]	A block of memory containing the vehicle operating conditions for a specific time.
Front Wheel Drive	FWD	A driveline configuration that transmits motive power only through the front axle.
Fuel Level Sensor	---	See Glossary Entries "FUEL" and "SENSOR."
Fuel Pressure	---	See Glossary Entries "FUEL" and "PRESSURE."
Fuel Pump	FP[2]	See Glossary Entries "FUEL" and "PUMP."
Fuel System Status	...[3]	Information describing operation of the fuel control. (i.e. Open Loop/Closed loop)
Fuel Trim[1]	FT	A fuel correction term.
Full Time Four Wheel Drive	F4WD	A driveline configuration that transmit motive power to both axles. The system does not allow the driver to select between one axle and two axle operation.
Generator	GEN[2]	See Glossary Entry "GENERATOR."
Glow Plug	---	See Glossary Entry "GLOW PLUG."
Governor	---	See Glossary Entry "GOVERNOR."
Governor Control Module	GCM[2]	See Glossary Entries "GOVERNOR," "CONTROL" and "MODULE."
Grams Per Mile	GPM	Grams of pollutant emitted per mile.
Ground	GND	See Glossary Entry "GROUND."
Heated Oxygen Sensor[1]	HO2S[2]	An oxygen sensor (IOS) that is electrically heated.
Idle Air Control[1]	IAC	Electrical or mechanical control of throttle bypass air.
Idle Speed Control[1]	ISC	Electronic control of minimum throttle position.
Ignition Control[1]	IC	See Glossary Entries "IGNITION" and "CONTROL."
Ignition Control Module[1]	ICM[2]	See Glossary Entries "IGNITION," "CONTROL" and "MODULE."
Indirect Fuel Injection[1]	IFI	An injection system that supplies fuel into a combustion pre-chamber (Diesel)
Inertia Fuel Shutoff	IFS	An inertia system that shuts off the fuel delivery system when activated by predetermined force limits.
Injection Control Pressure[1]	ICP	Injection control pressure for hydraulically actuated injectors.
Input Shaft Speed	ISS	See Glossary Entries "Input Shaft" and "Speed".
Inspection and Maintenance	I/M[2]	An emission control program.
Intake Air[1]	IA	See Glossary Entry "INTAKE AIR."
Intake Air Temperature[1]	IAT	See Glossary Entry "INTAKE AIR."
Intake Manifold Runner Control	IMRC	Controls air flow through runners in the intake manifold.
Knock Sensor[1]	KS[2]	See Glossary Entries "KNOCK" and "SENSOR."
Malfunction Indicator Lamp [1]	MIL[2]	A required on-board indicator to alert the driver of an emission related malfunction
Manifold Absolute Pressure[1]	MAP	See Glossary Entries "MANIFOLD" and "PRESSURE."
Manifold Differential Pressure[1]	MDP	See Glossary Entries "MANIFOLD" and "PRESSURE."
Manifold Surface Temperature[1]	MST	See Glossary Entry "MANIFOLD."
Manifold Vacuum Zone[1]	MVZ	See Glossary Entries "MANIFOLD" and "VACUUM."
Mass Air Flow[1]	MAF	A system which provides information on the mass flow rate of the intake air to the engine.
Mixture Control[1]	MC	A device which regulates bleed air, fuel, or both, on carbureted vehicles.
Multiport Fuel Injection[1]	MFI	A fuel-delivery system in which each cylinder is individually fueled.
Non Dispersive Infra Red	NDIR	An Emission measuring technique typically used for measuring carbon monoxide and carbon dioxide concentrations.
Non Volatile Random Access Memory[1]	NVRAM	An electronic device named non-volatile random access memory.
On Board Diagnostic[1]	OBD	A system that monitors some or all computer input and control signals. Signal(s) outside of the predetermined limits imply a fault in the system or in a related system.
Open Loop[1]	OL	See Glossary Entry "OPEN LOOP."
Output Shaft Speed [1]	OSS	See Glossary Entry "OUTPUT SHAFT " and "SPEED."
Oxidation Catalytic Converter[1]	OC	A catalytic converter system that reduces levels of HC and CO.
Oxygen Sensor[1]	O2S[2]	A sensor which detects oxygen (O2) content in the exhaust gases.
Park/Neutral Position[1]	PNP	See Glossary Entry "PARK/NEUTRAL."
Parameter Identification	PID	Identifies an address in memory which contains vehicle operating information.

TABLE 3--RECOMMENDED TERMS (CONTINUED)

Recommended Term	Acronym	Definition
Periodic Trap Oxidizer[1]	PTOX	A system for lowering diesel engine particulate emissions by collecting exhaust particulates and periodically burning them through oxidation.
Positive Crankcase Ventilation[1]	PCV	Positive ventilation of crankcase emissions.
Power Steering Pressure	PSP	See Glossary Entry "POWER STEERING."
Powertrain Control Module[1]	PCM[2]	See Glossary Entries "POWERTRAIN," "CONTROL" and "MODULE."
Pressure Control[1]	PC	See Glossary Entries "PRESSURE" and "CONTROL."
Programmable Read Only Memory[1]	PROM	An electronic device named programmable (by the manufacturer) read only memory.
Pulsed Secondary Air Injection[1]	PAIR[2]	A pulse-driven system for providing secondary air without an air pump by using the engine exhaust system pressure fluctuations or pulses.
Pulse Width Modulation	PWM	A rectangular wave with a variable on-off time.
Random Access Memory[1]	RAM	An electronic device named random access memory.
Read Only Memory[1]	ROM	An electronic device named read only memory.
Rear Wheel Drive	RWD	A drivetrain configuration that transmit motive power only through the rear axle.
Relay Module	RM[2]	See Glossary Entries "RELAY" and "MODULE."
Scan Tool[1]	ST[3]	See Glossary Entry "SCAN TOOL."
Secondary Air Injection[1]	AIR[3]	A pump-driven system for providing secondary air.
Selectable Four Wheel Drive	S4WD	A drivetrain configuration that allows the driver to select the option to transmit motive power either to both axles or only to one axle (front or rear).
Sequential Multiport Fuel Injection[1]	SFI	A multiport fuel delivery system in which each injector is individually energized and timed relative to its cylinder intake event. Normally fuel is delivered to each cylinder once per two crankshaft revolutions in four cycle engines and once per crankshaft revolution in two cycle engines.
Service Reminder Indicator[1]	SRI[2]	An indicator used to identify a service requirement.
Shift Solenoid	SS	See Glossary Entry "SHIFT SOLENOID ".
Smoke Puff Limiter[1]	SPL	A system to reduce diesel exhaust smoke during vehicle acceleration or gear changes.
Spark Advance	—[3]	The relationship between the ignition firing and top dead center.
Spark Plug[1]	—	A device for producing an electrical spark inside the cylinder of an internal combustion engine to ignite the fuel mixture.
Supercharger[1]	SC[2]	See Glossary Entry "SUPERCHARGER."
Supercharger Bypass[1]	SCB	See Glossary Entry "SUPERCHARGER."
System Readiness Test[1]	SRT	System readiness test as applicable to OBDII scan tool communications.
Thermal Vacuum Valve[1]	TVV[2]	A valve that controls vacuum levels or routing based on temperature.
Third Gear	3GR[2]	Identifies the gear in which the transmission is operating in at a particular moment (e.g., the Transmission Range (TR) switch may indicate that "drive" was selected, but the transmission is operating in 3rd gear as indicated by 3GR switch).
Three Way + Oxidation Catalytic Converter[1]	TWC+OC	A catalytic converter system that has both Three Way Catalyst (TWC) and Oxidation Catalyst (OC). Usually secondary air is introduced between the two catalysts.
Three Way Catalytic Converter[1]	TWC	A catalytic converter system that reduces levels of HC, CO and Nox.
Throttle Actuator Control	TAC	See Glossary Entries "THROTTLE", "ACTUATOR" and "CONTROL."
Throttle Body[1]	TB[2]	See Glossary Entries "THROTTLE" and "BODY."
Throttle Body Fuel Injection[1]	TBI	An electronically controlled fuel injection system in which one or more fuel injectors are located in a throttle body.
Track Road Load Horsepower	TRLHP	The power required for a vehicle to maintain a constant speed taking into account power losses due to such things as wind resistance, tire losses, bearing friction, etc.
Throttle Position[1]	TP	See Glossary Entry "THROTTLE."
Torque Converter Clutch[1]	TCC[2]	See Glossary Entries "CONVERTER" and "CLUTCH."
Torque Converter Clutch Pressure	TCCP	A positive pressure in a torque converter clutch hydraulic circuit.
Transmission Control Module	TCM[2]	See Glossary Entries "TRANSMISSION," "CONTROL" and "MODULE."
Transmission Fluid Pressure	TFP	Positive pressure in a transmission hydraulic system.
Transmission Fluid Temperature	TFT	Temperature of transmission fluid.
Transmission Range	TR	See Glossary Entries "TRANSMISSION" and "RANGE."
Turbine Shaft Speed[1]	TSS	See Glossary Entries "TURBINE SHAFT" and "SPEED."
Turbocharger[1]	TC[2]	See Glossary Entry "TURBOCHARGER."
Variable Control Relay Module	VCRM	A module that variably controls engine cooling fan speed, operates the A/C compressor clutch, and controls some of the main A/C functions.
Vehicle Control Module[1]	VCM[2]	An electronic module that controls the powertrain plus chassis and/or body related functions.
Vehicle Identification Number	VIN	A unique number on the vehicle used for identification.
Vehicle Speed Sensor[1]	VSS[2]	A sensor which provides vehicle speed information.
Voltage Regulator	VR	See Glossary Entry "REGULATOR."
Volume Air Flow[1]	VAF	A system which provides information on the volume flow rate of the intake air to the engine.
Warm Up Oxidation Catalytic Converter[1]	WU-OC	A catalytic converter system designed to lower HC and CO emissions during engine warm up. Usually located in or near the exhaust manifold.
Warm Up Three Way Catalytic Converter[1]	WU-TWC	A catalytic converter system designed to lower HC, CO, & NOx emissions during engine warm up. Usually located in or near the exhaust manifold.
Wide Open Throttle[1]	WOT	See Glossary Entry "THROTTLE."

— Use Recommended Term Only
[1] Emission-Related Term
[2] Historically acceptable common usage
[3] For Alphanumeric Descriptor see Table 4
Bold indicated mandatory entry

7. Glossary of Terms---Table 3 is an alphabetical listing of base words and single word modifiers, together with their definitions.

TABLE 3--GLOSSARY OF TERMS

Base word/Single Word Modifier	Definition
Accelerator Pedal	A foot operated device, which, directly or indirectly, controls the flow of fuel and/or air to the engine, thereby, controlling engine speed.
Accumulator	A vessel in which fluid is stored, usually at greater than atmospheric pressure.
Actuator	A mechanism for moving or controlling something indirectly instead of by hand. Compare: Solenoid, relay, and valve.
Air Conditioning	A vehicular accessory system that modifies the passenger compartment air by cooling and drying the air.
Alternator	See Generator.
Battery	An electrical storage device designed to produce a DC voltage by means of an electrochemical reaction.
Blower	A device designed to supply a current of air at a moderate pressure. A blower usually consists of an impeller assembly, a motor and a suitable case. The blower case is usually designed as part of a ventilation system. Compare: Fan.
Brake	A device for retarding motion, usually by means of friction.
Body	(1) The assembly of sheet metal components, windows, doors, seats, etc., that provide enclosures for passengers and/or cargo in a motor vehicle. It may or may not include the hood and fenders. (2) The primary, central or key part of a fastener.
Bypass	Providing a secondary path to relieve pressure in the primary passage.
Camshaft	A shaft on which grooved cams are mounted. The camshaft is used to regulate the opening and closing of the intake and exhaust valves.
Canister	An evaporative emission canister contains activated charcoal which absorbs fuel vapors and holds them until the vapors can be purged at an appropriate time.
Capacitor	An electrical device for accumulating and holding a charge of electricity.
Carburetor	A mechanism which automatically mixes fuel with air in the proper proportions to provide a desired power output from a spark ignition internal combustion engine.
Catalyst	A substance that can increase or decrease the rate of a chemical reaction between substances without being consumed in the process.
Chassis	The suspension, steering, and braking elements of a vehicle.
Circuit	A complete electrical path or channel, usually includes the source of electric energy. Circuit may also describe the electrical path between two or more components. May also be used with fluids, air or liquid.
Cleaner	A device used in the intake system of parts that require clean air. An air cleaner usually has a filter in it to trap particulates and only pass clean air through.
Closed Loop (Engine)	An operating condition or mode which enables modification of programmed instructions based on a feedback system.
Clutch	A mechanical device which uses mechanical, magnetic or friction type connections to facilitate engaging or disengaging of two shafts or rotating members.
Code	A system of symbols (as letters, numbers, or words) used to represent meaning of information.
Coil (Ignition)	A device consisting of windings of conductors around an iron core, designed to increase the voltage, and for use in a spark ignition system.
Control	A means or a device to direct and regulate a process or guide the operation of a machine, apparatus or system.
Converter (Catalytic)	An in-line, exhaust system device used to reduce the level of engine exhaust emissions.
Converter (Torque)	A device which by its design multiplies the torque in a fluid coupling between an engine and transmission/transaxle.
Coolant	A fluid used for heat transfer. Coolants usually contain additives such as rust inhibitors and antifreeze.
Cooler	A heat exchanger that reduces the temperature of the contained medium.
Crankshaft	The part of an engine which converts the reciprocating motion of the pistons to rotary motion.
Data	General term for information, usually represented by numbers, letters, symbols.
Device	A piece of equipment or a mechanism designed for a specific purpose or function. DO NOT use "Device" in naming.
Diagnostics	The process of identifying the cause or nature of a condition, situation or problem. To determine corrective action to repair of automotive systems.
Differential	(1) A device with an arrangement of gears designed to permit the division of power to two shafts. (2) See Pressure.
Distributor	A mechanical device designed to switch a high voltage secondary circuit from an ignition coil to spark plugs in the proper firing sequence.
Drive	A device which provides a fixed increase or decrease ratio of relative rotation between its input and output shafts.
Driver	A switched electronic device that controls output state.
Electrical	A type of device or system using resistors, motors, generators, incandescent lamps, switches, capacitors, batteries, inductors or wires. Compare: Electronic.
Electronic	(1) A type of device or system using solid state devices or thermionic elements such as diodes, transistors, integrated circuits, vacuum fluorescent displays and liquid crystal displays. (2) The storage, retrieval and display of information through media such as magnetic tape, laser disc, electronic read only memory (ROM) and random access memory (RAM). Compare: Electrical.
Engine	A machine designed to convert thermal energy into mechanical energy to produce force or motion.
Exhaust	
Fan	A device designed to supply a current of air. A fan may also have a frame, motor, wiring harness and the like. Compare: Blower
Fuel	Any combustible substance burned to provide heat or power. Typical fuels include gasoline and diesel fuel. Other types of fuel include ethanol, methanol, natural gas, propane or in combination.

TABLE 3—GLOSSARY OF TERMS (CONTINUED)

Basewords/Single Word Modifier	Definition
Generator	A rotating machine designed to convert mechanical energy into electrical energy.
Glow Plug	A combustion chamber heat generating device to aid starting diesel engines.
Governor	A device designed to automatically limit engine speed.
Ground	An electrical conductor used as a common return for an electric circuit(s) and with a relative zero potential.
Idle	Rotational speed of an engine with vehicle at rest and accelerator pedal not depressed.
Ignition	System used to provide high voltage spark for internal combustion engines.
Indicator	A device which visually presents vehicle condition information transmitted or relayed from some other source.
Injector	A device for delivering metered pressurized fuel to the intake system or the cylinders.
Input Shaft	A shaft in a device that is "driven" by the previous element in the powertrain.
Intake Air	Air drawn through a cleaner and distributed to each cylinder for use in combustion.
Knock (Engine)	The sharp, metallic sound produced when two pressure fronts collide in the combustion chamber of an engine.
Level	The magnitude of a quantity considered in relation to an arbitrary reference value.
Line	A generic service term used to describe a system of pipes, tubes and hoses.
Link (Electrical/Electronic)	Generic term used to indicate the existence of communication facilities between two points.
Manifold	A device designed to collect or distribute fluid, air or the like. Compare: Rail.
Memory	A device in which data can be stored and used when needed.
Mode	One of several alternative conditions or methods of operating a device or control module.
Module (Electrical/Electronic)	A self-contained group of electrical/electronic components, which is designed as a single replaceable unit.
Motor	A machine that converts kinetic energy, such as electricity, into mechanical energy. Compare: Actuator.
Open Loop	An operating condition or mode based on programmed instructions and not modified by a feedback system.
Output Shaft	A shaft in a device that drives the next element in the powertrain.
Park/Neutral	The selected non-drive modes of the transmission.
Power Steering	A system which provides additional force to the steering mechanism, reducing the driver's steering effort.
Powertrain	The elements of a vehicle by which motive power is generated and transmitted to the driven axles.
Pressure	Unless otherwise noted, is gage pressure.
Pressure (Absolute)	The pressure referenced to a perfect vacuum.
Pressure (Atmospheric)	The pressure of the surrounding air at any given temperature and altitude. Sometimes called Barometric Pressure.
Pressure (Barometric)	Pertaining to atmospheric pressure or the results obtained by using a barometer.
Pressure (Differential)	The pressure difference between two regions, such as between the intake manifold and the atmospheric pressure.
Pressure (Gage)	The amount by which the total absolute pressure exceeds the ambient atmospheric pressure.
Pump	A device used to raise, transfer, or compress fluids by suction, pressure or both.
Radiator	A radiator is a liquid to air heat transfer device having a tank(s) and core(s) specifically designed to reduce the temperature of the coolant in an internal combustion engine cooling system.
Rail	A manifold for fuel injection fuel. Compare: Manifold
Range	The detent position of the transmission manual valve.
Refrigerant	A substance used as a heat transfer agent in an air conditioning system.
Relay	A generally electromechanical device in which connections in one circuit are opened or closed by changes in another circuit. Compare: Actuator, Solenoid, and Switch.
Regulator (Voltage)	A device that automatically controls the functional output of another device by adjusting the voltage to meet a specified value.
Scan Tool	A device that interfaces with and communicates information on a data link.
Secondary Air	Air provided to the exhaust system.
Sensor	The generic name for a device that senses either the absolute value or a change in a physical quantity such as temperature, pressure or flow rate, and converts that change into an electrical quantity signal. Compare: Transducer.
Shift Solenoid	A device that controls shifting in an automatic transmission.
Signal (Electrical/Electronic)	A fluctuating electric quantity, such as voltage or current, whose variations represent information.
Solenoid	A device consisting of an electrical coil which when energized, produces a magnetic field in a plunger, which is pulled to a central position. A solenoid may be used as an actuator in a valve or switch. Compare: Actuator, Relay, and Switch.
Solid State	Crystalline circuit structures used to perform electronic functions. Examples of such structures include transistors, diodes, integrated circuits and other semiconductors.
Speed	The magnitude of velocity (regardless of direction).
Supercharger	A mechanically driven device that pressurizes the intake air, thereby increasing the density of charge air and the consequent power output from a given engine displacement.
Switch	A device for making, breaking, or changing the connections in an electrical circuit. Compare: Relay, Solenoid, and Valve.
System	A group of interacting mechanical or electrical components serving a common purpose.
Test	A procedure whereby the performance of a product is measured under various conditions.
Throttle	A valve for regulating the supply of a fluid, usually air or a fuel/air mix, to an engine.
Transaxle	A device consisting of a transmission and axle drive gears assembled in the same case. Compare: Transmission.
Transducer	A device that receives energy from one system and retransmits (transfers) it, often in a different form, to another system. For example, the cruise control transducer converts a vehicle speed signal to a modulated vacuum output to control a servo. Compare: Sensor.
Transmission	A device which selectively increases or decreases the ratio of relative rotation between its input and output shafts.

TABLE 3—GLOSSARY OF TERMS (CONTINUED)

Recommended/Single Word Modifier	Definition
	Compare: Transaxle.
Troubleshooting	See Diagnostics.
Turbine Shaft	A shaft in a device that is driven by a turbine.
Turbocharger	A centrifugal device driven by exhaust gases that pressurize the intake air, thereby increasing the density of charge air and the consequent power output from a given engine displacement.
Ultraviolet	The portion of the electromagnetic spectrum between violet visible light and X-Rays.
Vacuum	A circuit in which pressure has been reduced below the ambient atmospheric pressure.
Valve	A device by which the flow of liquid, gas, vacuum, or loose material in bulk may be started, stopped or regulated by a movable part that opens, shuts or partially obstructs one or more ports or passageways. A "Valve" is also the moveable part of such a device. Compare: Actuator and Switch.
Vapor	A substance in its gaseous state as distinguished from the liquid or solid state.
Volatile	(1) Vaporizable at normal temperatures. (2) Not permanent.
Wastegate	A valve used to limit charge air pressure by allowing exhaust gases to bypass the turbocharger.
Wheel	A circular frame of hard material that may be solid, partially solid, or spoked and that is capable of turning on an axle.

Bold indicates new/revised entry

(R) *8. Alphanumeric Descriptor Table*—Table 4 is an alphabetical listing of alphanumeric descriptors to be used when required due to limited display sizes.

9. Revision Procedures—It will be appropriate to revise the published J1930 on an ongoing basis. Requested revisions and updates will be controlled by the SAE Vehicle E/E Systems Diagnostics Standards Committee using the annual Recommended Practice Ballot process. This will ensure proper distribution of the changes.

As required by SAE standards, the J1930 document will be formally updated and balloted at least once every five years. When warranted by the number of requested modifications, J1930 will be updated as often as every three months.

Use Appendix A for submission of new information.

TABLE 4—ALPHANUMERIC DESCRIPTOR TABLE

Recommended Term	Acceptable Acronym/ Usage	Alphanumeric Descriptor
Diagnostic Trouble Code	DTC Freeze Frame	DTC FRZF
Freeze Frame		
Freeze Frame	Freeze Frame	FRZF
Fuel Pressure	Fuel Pressure	FUEL PRES
Fuel System Status	Fuel System Status	FUEL SYS
Long Term Fuel Trim	Long Term FT	LONG FT
OBD Status	OBD Status	OBD STAT
Oxygen Sensor Location	O2S Location	O2S LOC
Parameter Identification Supported	PID Supported	PID SUP
Short Term Fuel Trim bp	Short Term FT bp	SHRT FT bp
Spark Advance	Spark Advance	SPARK ADV

b = bank
p = position
Bold indicates new/revised entry

APPENDIX A

REQUEST FOR REVISION to SAE J1930
ELECTRICAL / ELECTRONIC SYSTEMS
DIAGNOSTIC TERMS, DEFINITIONS, ABBREVIATIONS & ACRONYMS

To insure that your request is accepted for ballot and incorporation into J1930, please supply the following information consistent with the Methodology of Section 4:

Please send completed form to: SAE J1930 Task Force, 3001 West Big Beaver Rd, Ste. 320, Troy MI 48084-3174 U.S.A. fax no.: (810) 560-0625

PURPOSE or RATIONALE FOR REQUEST:

SECTION 5.0
EXISTING USAGE(S)

RECOMMENDED TERMS

SECTION 5.0	Add	Delete	Change
RECOMMENDED TERM			
EXISTING:	○	○	○
SUGGESTED:			
ACRONYM / ABBREVIATIONS			
EXISTING:	○	○	○
SUGGESTED:			
DEFINITION			
EXISTING:			
SUGGESTED:	○	○	○

EMISSION RELATED? YES ____ NO ____

SECTION 7.0
GLOSSARY of TERMS

(R) SECTION 8.0
ALPHANUMERIC DESCRIPTOR
DESIRED

REQUESTOR: Phone: Fax:

Signature Date

Address:

COMMITTEE USE ONLY

RECOMMEND FOR BALLOT ? YES ____ NO ____ BALLOT TARGET DATE ____
COMMENTS:

J1930 CHAIRPERSON ____ DATE ____

FIGURE A1—REQUEST FOR REVISION FORM

Report of the SAE Vehicle E/E Systems Diagnostic Standards Committee approved June 1992, completely revised June 1995, revised June 1994 and January 1995. Rationale statement available.

Foreword—The purpose of this SAE Recommended Practice is to define a minimum set of diagnostic connector requirements that will promote the use of a common diagnostic connector throughout the motor vehicle industry.

It is intended that the connector specified herein be used on complex luxury vehicles as well as simple utility vehicles.

This SAE document is under the control and maintenance of the Vehicle E/E System Diagnostics Committee. This committee will periodically review and update this document as needs dictate.

Rationale relative to intent is provided, where applicable, to minimize ambiguity.

TABLE OF CONTENTS

Foreword

1. Scope
2. References
2.1 Applicable Documents
2.1.1 SAE Publications
2.1.2 ISO Publications
2.1.3 Other Publications
2.2 Diagnostic Terms, Definitions, and Acronyms
3. Vehicle Connector Location/Access
3.1 Consistency of Location
3. Ease of Access
3.3 Visibility
3.4 Vehicle Operation
4. Vehicle and Test Equipment Connector Design
4.1 Previous Designs Acceptable
4.2 Number of Terminals
4.3 Terminal Requirements
4.3.1 Terminal Types
4.3.2 Terminal Spacing
4.4 Connector Mating
4.5 Connector Shape/Features
4.6 Spring Clip
4.7 Material Selection
4.7.1 Connector Material
4.7.2 Terminal Material
4.8 Vehicle Connector Cycle Life
4.9 Test Equipment Connector Cycle Life
4.10 Strain Relief
4.11 Terminal and Connector Parameters and Performance Requirements
4.11.1 Functional Parameters for Terminals
4.11.2 Performance Requirements for Terminals
4.11.3 Connector System Performance Requirements
4.11.4 Accelerated Environmental Exposures for the Vehicle Connector
5. Vehicle and Test Equipment Connector Terminal Assignments
5.1 Vehicle and Test Equipment Connector Terminal Identification
5.2 General Terminal Assignments
5.3 Vehicle Connector Terminal Assignments
5.3.1 Vehicle Connector Terminals - General Limits
5.3.2 Vehicle Connector Terminals 1, 3, 6, 8, 9, 11, 12, 13, and 14
5.3.3 Vehicle Connector Terminal 2
5.3.4 Vehicle Connector Terminal 4
5.3.5 Vehicle Connector Terminal 5
5.3.6 Vehicle Connector Terminal 7
5.3.7 Vehicle Connector Terminal 10
5.3.8 Vehicle Connector Terminal 15
5.3.9 Vehicle Connector Terminal 16
5.4 Vehicle Connector Terminal Protection
5.5 Test Equipment Connector Terminal Assignments
5.5.1 Test Equipment Connector Terminals - General Limits
5.5.2 Test Equipment Connector Terminals 1, 3, 6, 8, 9, 11, 12, 13, and 14
5.5.3 Test Equipment Connector Terminals 2, 7, 10, and 15
5.5.4 Test Equipment Connector Terminal 4
5.5.5 Test Equipment Connector Terminal 5
5.5.6 Test Equipment Connector Terminal 16
5.6 Test Equipment Connector Terminal Protection
6. Minimum Current Available
7. Liability for Devices That Draw More Than 4.0 A

1. Scope—The SAE J1962 diagnostic connector consists of two mating connectors, the vehicle connector (see Figure 1) and the test equipment connector (see Figure 2).

This document:

a. Defines the functional requirements for the vehicle connector. These functional requirements are separated into three principal areas: connector location/access, connector design, and connector terminal assignments.

b. Defines the functional requirements for the test equipment connector. These functional requirements are separated into two principal areas: connector design and connector terminal assignments.

The scope of this document does not include the needs of long-term retention, such as in-flight recorder type applications. To ensure long-term retention, additional steps outside of the scope of this document must be taken.

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 J1850—Class B Data Communication Network Interface

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

SAE J1978—OBD II Scan Tool

SAE J2201—OBD II Scan Tool Universal Interface

(R) SAE J2223-3—Connections for On-Board Road Vehicle Electrical Wiring Harnesses—Part 3: Multipole Connectors—Flat Blade Terminals—Dimensional Characteristics and Specific Requirements

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

ISO 9141-2:1994(E)—Road vehicles—Diagnostic systems—CARB requirements for interchange of digital information ISO 8092-3—Road vehicles—Flat, quick connection terminations

(R) 2.1.3 OTHER PUBLICATIONS

California Code of Regulations, Title 13, 1968.1: Malfunction and Diagnostic Systems Requirements, - 1994 and subsequent model year passenger cars, light-duty trucks, and medium-duty vehicles with feedback fuel control systems

Environmental Protection Agency 40 CFR Part 86 Control of Air Pollution From New Motor Vehicles and New Motor Vehicle Engines; Regulations Requiring On-Board Diagnostic Systems on 1994 and Later Model Year Light-Duty Vehicles and Light-Duty Trucks

2.2 Diagnostic Terms, Definitions, and Acronyms—SAE J1930 is hereby referenced as the basis for all such terms in this document, with the following additions:

N Newtons

SAE J1850 10.4 VPW - SAE J1850 One wire, 10.4 Kbps, VPW

SAE J1850 41.6 PWM - SAE J1850 Two wire, 41.6 Kbps, PWM

3. Vehicle Connector Location/Access

3.1 Consistency of Location—The vehicle connector shall be located in the passenger compartment in the area bounded by the driver's end of the instrument panel to 300 mm beyond the vehicle centerline, attached to the instrument panel, and accessible from the driver's seat. The preferred location is between the steering column and the vehicle centerline. The vehicle connector shall be mounted to facilitate mating and unmating.

3.2 Ease of Access—Access to the vehicle connector shall not require a tool for the removal of an instrument panel cover, connector cover, or any barriers. The vehicle connector should be fastened and located so as to permit a one-handed/blind insertion of the mating test equipment connector. Refer to Figure 1 for mated connector space requirements.

3.3 Visibility—The vehicle connector should be out of the occupant's (front and rear seat) normal line of sight but easily visible to a "crouched" technician.

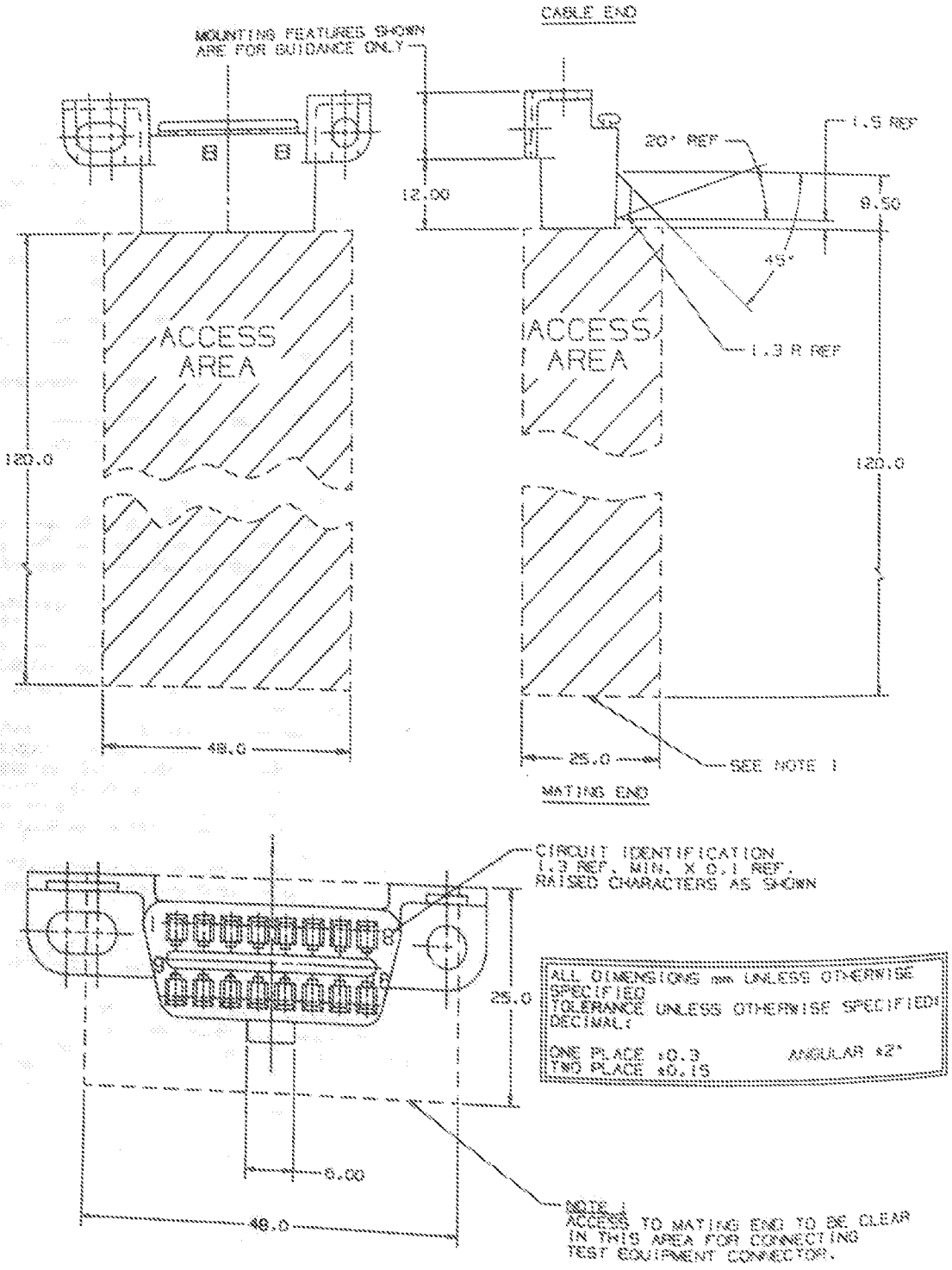


FIGURE 1—VEHICLE CONNECTOR

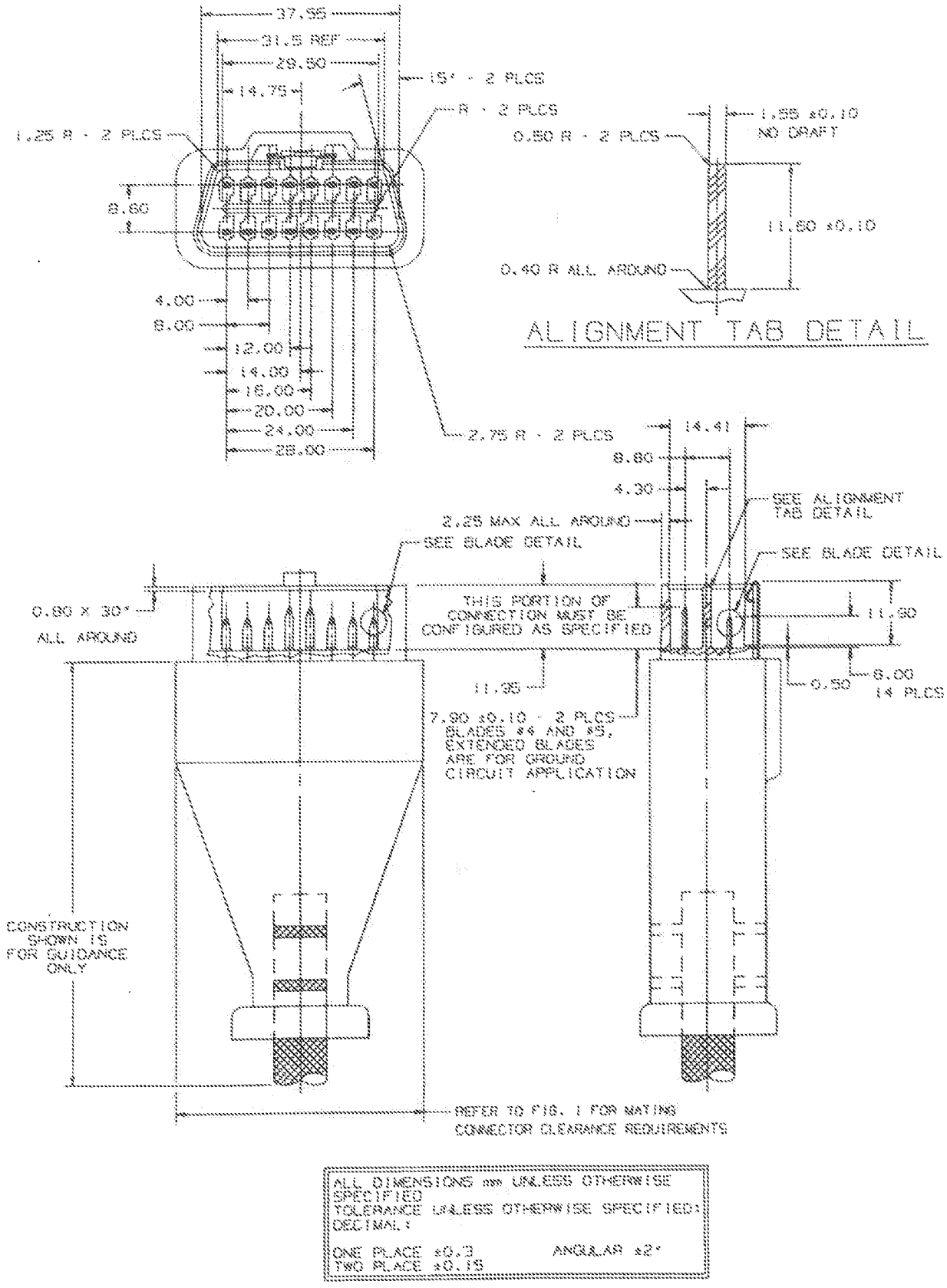


FIGURE 2—TEST EQUIPMENT CONNECTOR

3.4 Vehicle Operation—Attachment of any equipment to the vehicle connector should not preclude normal physical and electrical operation of the vehicle.

4. Vehicle and Test Equipment Connector Design

4.1 Previous Designs Acceptable—This version of this document includes changes to some of the dimensions of the Vehicle Connector and the Test Equipment Connector. Vehicle Connectors and Test Equipment Connectors manufactured to the specifications of the previous versions of this document that are compatible with connectors designed to the specifications of this document are acceptable. The specification changes made to the Test Equipment Connector were made to prevent potential bent terminal problems with the two extended ground terminals in the Test Equipment Connector.

4.2 Number of Terminals—The vehicle and test equipment connectors shall each be capable of accommodating 16 terminals.

4.3 Terminal Requirements—The terminals shall be rated for currents not to exceed 10 A DC continuous.

4.3.1 TERMINAL TYPES—The vehicle connector shall consist of female terminals that will mate with the test equipment connector male blade terminals.

4.3.2 TERMINAL SPACING—Terminal spacing is shown in Figure 2.

4.4 Connector Mating—The test equipment connector contact mating shall be designed so that the signal ground and the chassis ground terminals of the test equipment connector will make electrical contact prior to any other test equipment connector terminals making electrical contact. On the disconnect cycle, these same two terminals will not lose electrical contact until all of the other terminals have been disconnected.

4.5 Connector Shape/Features—The mating portions of both connectors shall be "D" shaped. The connectors shall have easily discernible keying features to allow for easy connection in a one-handed/blind operation.

The vehicle connector and the test equipment connector shall have latching features that assure the test equipment connector will remain mated when properly connected. The latching feature will be designed to provide a positive feel when the test equipment connector is fully seated. The latching feature should not require the activation of any levers on either connector to mate or unmate. Pulling on the test equipment connector to separate the two mated halves shall not result in any damage to either connector.

4.6 Spring Clip—An optional Spring Clip (see Figure 3) may be used on the Test Equipment Connector.

4.7 Material Selection

4.7.1 CONNECTOR MATERIAL—Selection and specification of connector material shall be made by the appropriate vehicle and test equipment manufacturers. However, the minimum recommended temperature range for the selected material is −40 to 85 °C.

4.7.2 TERMINAL MATERIAL—Selection and specification of terminal base material shall be made by the appropriate vehicle and test equipment manufacturers.

Selection of terminal material, especially plating if any, may be a significant factor to the durability of the terminals in the vehicle connector and/or the test equipment connector. Different applications of these connectors generally will require selection of different terminal material/plating, especially for the test equipment connector.

4.8 Vehicle Connector Cycle Life—The vehicle connector shall meet the requirements of this document after 200 mating cycles.

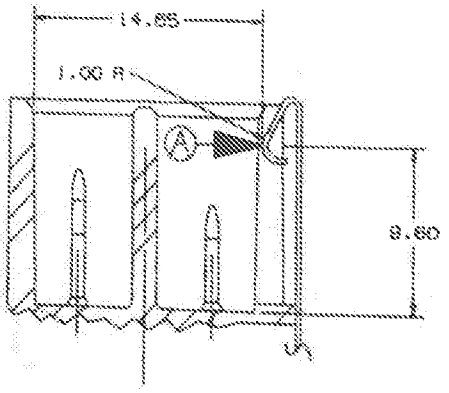
4.9 Test Equipment Connector Cycle Life—The test equipment manufacturer shall specify the minimum number of mating cycles the test equipment connector is capable of while meeting the requirements of this document.

4.10 Strain Relief—The test equipment connector shall have strain relief features for the wires/cable connected to it.

4.11 Terminal and Connector Parameters and Performance Requirements

4.11.1 FUNCTIONAL PARAMETERS FOR TERMINALS

a. Blade Size for Test Equipment Connector: Shall conform to the dimensions shown in Figure 4
b. Maximum Current DC: 10 A DC continuous
c. Temperature Range: −40 to +85 °C
d. Voltage Range DC: −0.05 to 30.0 V DC
e. Suggested Maximum Cable Size: 0.8 mm^2 (18 AWG)



ALL DIMENSIONS mm UNLESS OTHERWISE SPECIFIED
TOLERANCE UNLESS OTHERWISE SPECIFIED:
DECIMALS
ONE PLACE ±0.3
TWO PLACE ±0.15
ANGULAR ±2°

NOTE: SPRING CLIP PERFORMANCE

A FORCE APPLIED AS SHOWN BY ARROW "A" MUST DEFLECT CLIP OUTWARD FOR A DISTANCE OF 2.50 ±0.15 MM. CLIP MUST RECOVER TO ORIGINAL POSITION. CONNECTOR MUST MEET SPECIFICATION SHOWN IN 5.8.2.2 CONNECTOR MATING FORCE WITH 16 TERMINALS WITH SPRING CLIP, WITH SPRING CLIP IN PLACE.

FIGURE 3—SPRING CLIP DETAIL (Optional)

4.11.2 PERFORMANCE REQUIREMENTS FOR TERMINALS—The terminal system (i.e., mated terminal pairs) must meet the performance standards in (a) through (e) following each of the environmental exposures listed in 4.11.4. Performance measurements are to be taken at room temperature.

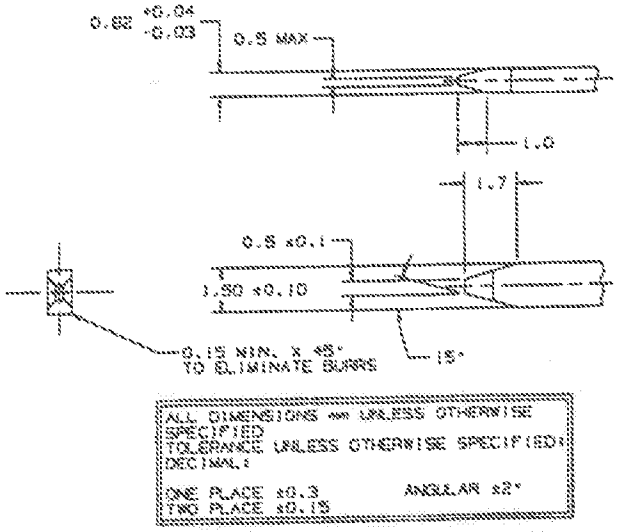
a. Resistance Interface (measured at 1 A): 3 mΩ maximum
b. Recommended Resistance Cable to Cable per Terminal Pair (measured at 1 A): 10 mΩ maximum
c. Recommended Low Energy Resistance: 100 mΩ maximum at 100 μA at 20 mV (open circuit voltage) at initial mating

4.11.3 CONNECTOR SYSTEM PERFORMANCE REQUIREMENTS—The connector system must meet the performance standards outlined in (a) through (f) following each of the environmental exposure listed in 4.11.4. Performance measurements must be taken at room temperature.

a. Isolation Resistance—Between adjacent terminals must exceed 20 MΩ at 16 V DC.
b. Retention Force—Terminal to connector retention force to exceed 80 N.
c. Connector Disengagement Force with 16 terminal pairs—Not to exceed 88 N.
d. Connector Mating Force with 16 terminal pairs:
   (1) without spring clip 110 N maximum
   (2) with spring clip 142 N maximum (see Figure 3)
e. Indexing Feature—Must prevent mismating of connectors when a force of 300 N is applied.
f. Mounting Feature—The vehicle connector mounting feature shall withstand a 300 N force applied to the connector mating area in the direction of the mating and unmating process.

4.11.4 ACCELERATED ENVIRONMENTAL EXPOSURES FOR THE VEHICLE CONNECTOR—Accelerated environmental testing shall be conducted for the vehicle connector while not being mated to the test equipment connector. Following each environmental exposure, the vehicle connector shall be mated to an unused test equipment connector for the performance measurements specified in sections 4.11.2 and 4.11.3.

a. Thermal Cycling—1000 cycles of 30 min at −40 °C and 30 min at 110 °C.
b. Temperature/Humidity Cycling—15 cycles of the following:
   16 h at 95% RH and 40 °C
   2 h at −40 °C
   2 h at +85 °C
   4 h at room temperature
c. Mechanical Shock—3 shocks of 50 G in each of 3 mutually perpendicular axes.
d. Vibration—Sinusoidal 1.5 mm ± 0.15 mm amplitude by 15 G for 2 h in each of 3 mutually perpendicular axes.



BLADE DIMENSIONS FOR THE 1.5 mm x 0.8 mm BLADE PER ISO 8092-3 OR SAE J2223-3 ARE ALSO ACCEPTABLE

FIGURE 4—BLADE DETAIL

5. Vehicle and Test Equipment Connector Terminal Assignments

5.1 Vehicle and Test Equipment Connector Terminal Identification—See Figure 5 for vehicle connector and test equipment connector terminal identifications.

5.2 General Terminal Assignments—See Figure 6 for a summary of terminal assignments.

5.3 Vehicle Connector Terminal Assignments

5.3.1 VEHICLE CONNECTOR TERMINALS - GENERAL LIMITS—All uses of all terminals of vehicle connector are limited to the range of −0.05 to 30.0 V DC.

5.3.2 VEHICLE CONNECTOR TERMINALS 1, 3, 6, 8, 9, 11, 12, 13, AND 14—Assignments of vehicle connector terminals 1, 3, 6, 8, 9, 11, 12, 13, and 14 is left to the discretion of the vehicle manufacturer.

5.3.3 VEHICLE CONNECTOR TERMINAL 2—If SAE J1850 10.4 VPW is used in a vehicle to supply OBD II required communication services, then terminal 2 of the vehicle connector must be the SAE J1850 10.4 VPW connection.

If SAE J1850 41.6 PWM is used in a vehicle to supply OBD II required communication services, then terminal 2 of the vehicle connector must be the Bus + Signal of the SAE J1850 41.6 PWM connection.

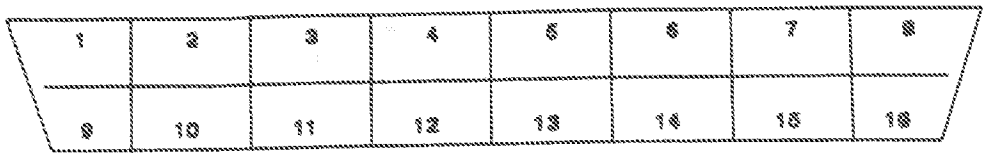


FIGURE 5—VEHICLE CONNECTOR MATING END VIEW

If neither SAE J1850 10.4 VPW nor SAE J1850 41.6 PWM is used in a vehicle to supply OBD II required communication services, then assignment of this terminal is left to the discretion of the vehicle manufacturer, provided this assignment does not interfere with the operation of, nor cause damage to, tools conforming to SAE J1978.

5.3.4 VEHICLE CONNECTOR TERMINAL 4—Vehicle connector terminal 4 is designated Chassis Ground and must be connected to the vehicle in such a way as to provide a power ground for test equipment taking current as defined in SAE J1978. Paragraph 5.5.4 defines the use of this terminal by test equipment.

5.3.5 VEHICLE CONNECTOR TERMINAL 5—Vehicle connector terminal 5 is designated Signal Ground and must be implemented in the vehicle connector in such a way as to provide a ground reference for the communication transceivers in test equipment and as a possible power ground for test equipment taking current as defined in SAE J1978. Its implementation in the vehicle must take into consideration noise contributions and node to node voltage offset limitations of the OBD II communication interface used in the vehicle. The use of a battery minus (–), common vehicle clean signal ground, "clean," "logic," or other connection points within a vehicle that minimize node to node voltage offsets and noise is recommended. Paragraph 5.5.5 defines the use of this terminal by test equipment.

Terminal	General Assignment
1	Discretionary*
2	Bus + Line of SAE J1850 **
3	Discretionary*
4	Chassis Ground
5	Signal Ground
6	Discretionary*
7	K Line of ISO 9141-2 **
8	Discretionary*
9	Discretionary*
10	Bus - Line of SAE J1850 **
11	Discretionary*
12	Discretionary*
13	Discretionary*
14	Discretionary*
15	L Line of ISO 9141-2 **
16	Unswitched Vehicle Battery Positive

* Note, assignment of terminals 1, 3, 6, 8, 9, 11, 12, 13, and 14 in the vehicle connector is left to the discretion of the vehicle manufacturer.

** Note, for terminals 2, 7, 10, and 15 the related OBD II communication assignments are shown. These terminals may also be used for different assignments in the vehicle connector. See the section titled Vehicle Connector Terminal Assignments and the section titled Test Equipment Connector Terminal Assignments for further information.

FIGURE 6—GENERAL TERMINAL ASSIGNMENTS

5.3.6 VEHICLE CONNECTOR TERMINAL 7—If a two wire or a one wire ISO 9141-2 interface is used in a vehicle to supply OBD II required communication services, then terminal 7 of the vehicle connector must be the K Line of the ISO 9141-2 interface.

If neither a two wire nor a one wire ISO 9141-2 interface is used in a vehicle to supply OBD II required communication services, then assignment of this terminal is left to the discretion of the vehicle manufacturer, provided this assignment does not interfere with the operation of, nor cause damage to, tools conforming to SAE J1978.

5.3.7 VEHICLE CONNECTOR TERMINAL 10—If an SAE J1850 41.6 PWM interface is used in a vehicle to supply OBD II required communication services, then terminal 10 of the vehicle connector must be the Bus – signal of the SAE J1850 41.6 PWM interface.

If an SAE J1850 41.6 PWM interface is not used in a vehicle to supply OBD II required communication services, then assignment of this terminal is left to the discretion of the vehicle manufacturer, provided this assignment does not interfere with the operation of, nor cause damage to, tools conforming to SAE J1978.

5.3.8 VEHICLE CONNECTOR TERMINAL 15—If a two wire ISO 9141-2 interface is used in a vehicle to supply OBD II required communication services, then terminal 15 of the vehicle connector must be the L Line of the ISO 9141-2 interface.

If a two wire ISO 9141-2 interface is not used in a vehicle to supply OBD II required communication services, then assignment of this terminal is left to the discretion of the vehicle manufacturer, provided this assignment does not interfere with the operation of, nor cause damage to, tools conforming to SAE J1978.

(R) 5.3.9 VEHICLE CONNECTOR TERMINAL 16—Vehicle connector terminal 16 is designated Unswitched Vehicle Battery Positive and must be implemented in the vehicle connector. This terminal must be connected directly (i.e., unswitched) to the DC Positive of the vehicle's battery. This connection does not preclude the use of a fuse or other circuit protection elements. This circuit may be grouped with other similar circuits. This terminal must be able to supply a minimum of 4.0 A.

5.4 Vehicle Connector Terminal Protection—It is recommended that the vehicle manufacturer provide circuit protection in the event that the terminals of the vehicle connector are shorted together. This protection is limited to the ranges of voltages present at the vehicle connector before the test equipment connector is mated to it.

5.5 Test Equipment Connector Terminal Assignments

5.5.1 TEST EQUIPMENT CONNECTOR TERMINALS—GENERAL LIMITS—All uses of all terminals of test equipment connector are limited to the range of –0.05 to 30.0 V DC.

5.5.2 TEST EQUIPMENT CONNECTOR TERMINALS 1, 3, 6, 8, 9, 11, 12, 13, AND 14—The use of test equipment connector terminals 1, 3, 6, 8, 9, 11, 12, 13, and 14 is left to the discretion of the test equipment manufacturer.

These test equipment connector terminals shall normally be in a high impedance state, that is at greater than500 kΩ impedance relative to Signal Ground and at greater than 500 kΩ impedance relative to Chassis Ground.

Before the condition of these test equipment connector terminals is changed from this high impedance state, the test equipment user and/or the test equipment must verify the proper usage of these vehicle connector terminals.

5.5.3 TEST EQUIPMENT CONNECTOR TERMINALS 2, 7, 10, AND 15—Assignment and use of test equipment connector terminals 2, 7, 10, and 15 must be compatible with the assignment and use of their mating terminal in the vehicle connector (see 5.3) and SAE J2201.

5.5.4 TEST EQUIPMENT CONNECTOR TERMINAL 4—Test equipment connector terminal 4 is designated Chassis Ground and is defined by SAE J2201. This terminal may be used by test equipment as a power ground. Implementation of this terminal in the test equipment connector is optional.

(R) 5.5.5 TEST EQUIPMENT CONNECTOR TERMINAL 5—Test equipment connector terminal 5 is designated Signal Ground and is defined by SAE J2201. This terminal must be used by the SAE J1978 OBD II Scan Tool as the signal reference for communication transceivers. This terminal must be implemented in the test equipment connector for support of SAE J2201. Test equipment must not draw more than 1.5 A through this terminal. (Note that the 1.5 A limit refers to uses of test equipment covered by this document [i.e., support of the requirements of SAE J1978]. Support of other uses of the SAE J1962 connectors [e.g., connecting a vehicle manufacturer discretionary terminal to ground] is not covered by this limitation.)

5.5.6 TEST EQUIPMENT CONNECTOR TERMINAL 16—Test equipment connector terminal 16 is designated as Unswitched Vehicle Battery Positive and is available to supply operating power and a reference voltage to test equipment.

5.6 Test Equipment Connector Terminal Protection—It is recommended that all circuits connected to the terminals of the test equipment connector be protected to the extent that no damage will come to these circuits if ANY terminal of the test equipment connector:

(R)
a. Is connected to vehicle connector terminal 16 - Unswitched Vehicle Battery Positive for up to 10 A,
b. Is connected to vehicle connector terminal 4 - Vehicle Chassis Ground, or
c. Is connected to vehicle connector terminal 5 - Vehicle Signal Ground.

(R) 6. *Minimum Current Available*—In order to ensure that adequate current is available to operate diagnostic scan tools, the minimum current available through terminal 16 of the vehicle connector shall be no less than 4.0 A.

The vehicle manufacturer shall not be responsible for supplying more than 4.0 A.

(R) 7. *Liability for Devices That Draw More Than 4.0 A*—Manufacturers of devices that include a connection to the vehicle connector, and which draw in excess of 4.0 A from terminal 16 of the vehicle connector, may be responsible for any damage to the vehicle.

Report of the SAE E/E Systems Diagnostic Standards Committee approved March 1992 and revised June 1994.

Foreword—Title 13, California Code of Regulations, Section 1968.1 "Malfunction and Diagnostic System Requirements 1994 and Subsequent Model Year Passenger Cars, Light Duty Trucks, and Medium Duty Vehicles With Feedback Control Systems," more commonly known as OBD II (On-Board Diagnostics version II), defines diagnostic functions required to be supported by vehicles and functions to be supported by test equipment that interface with the vehicle diagnostic functions.

While a range of test equipment (e.g. handheld scan tools, PC based diagnostic computers, etc.) may be used to perform the required interface support functions, the term OBD II Scan Tool is used in this document to refer to any test equipment that meets the requirements of this document.

TABLE OF CONTENTS

Foreword
1. Scope
2. References
2.1 Applicable Documents
2.1.1 SAE Publications
2.1.2 ISO Publications
2.1.3 Other Publications
3. Application
4. Diagnostic Terms, Definitions, and Acronyms
5. Required Functions
6. Vehicle Interface
6.1 Communication Data Link and Physical Layers
6.1.1 SAE J1850 Recommended Practice Class B Data Communication Network Interface
6.1.2 ISO 9141-2:1994(E) Road Vehicles—Diagnostic Systems—CARB Requirements for Interchange of Digital Information
6.2 Connector
6.3 Messages
6.4 Expanded Diagnostic Protocol
6.5 Automatic Hands-off Determination of the Communication Interface Used in a Given Vehicle
6.5.1 General
6.5.2 Initialization Details
6.6 On-Board Diagnostic Evaluations
6.6.1 Completed On-Board System Readiness Tests
6.6.2 Supported On-Board System Readiness Tests
6.6.3 Malfunction Indicator Light
6.7 Use of SAE J2201 Universal Interface for OBD II Scan Tools
6.8 Handling of No Response From Vehicle
6.9 Connections to the Vehicle in Addition to the SAE J1962 Diagnostic Connector
7. System Interaction Capability
7.1 Obtain and Display OBD II Emissions Related Diagnostic Trouble Codes
7.2 Obtain and Display OBD II Emissions Related Current Data, Freeze Frame Data, and Test Parameters and Results
7.3 Responses from Multiple Modules
7.4 Code Clearing
8. General Characteristics
8.1 Display
8.2 User Input
9. Power Requirements if Powered by the Vehicle Through the SAE J1962 Diagnostic Connector
10. Electromagnetic Compatibility (EMC)
11. Conformance Testing
11.1 General
11.2 Determine OBD II Communication Type
11.3 On-Board System Readiness Tests
11.4 Select Functions
11.5 Select and Display Items
11.6 Verify Requests to Clear Codes
11.7 General Diagnostic Communication Tests
11.8 Expanded Diagnostic Protocol
11.9 Capacitance and Impedance at the SAE J1962 Connector
11.10 Operating Voltage and Current Draw
11.11 Protocol Check
11.12 Alphanumeric Display
11.13 User Manual and Help Facility

1. Scope—This SAE Recommended Practice defines the requirements of OBD II Scan Tools, i.e., test equipment that will interface with vehicle modules in support of the OBD II diagnostic requirements. It covers the required capabilities of and conformance criteria for OBD II Scan Tools.

2. References

2.1 Applicable Documents—The following publications form a part of this specification to the extent specified herein. The latest issues 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 (Except Aircraft)

SAE J1850—Class B Data Communication Network Interface

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

SAE J1962—Diagnostic Connector

SAE J1979—E/E Diagnostic Test Modes

SAE J2012—Recommended Format and Messages for Diagnostic Trouble Codes

SAE J2201—Universal Interface for OBD II Scan Tools

SAE J2205—Expanded Diagnostic Protocol

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

ISO 7637—Road vehicles—Electrical disturbance by condition and coupling

ISO 9141-2:1994(E)—Road vehicles—Diagnostic systems—CARB requirements for interchange of digital information

2.1.3 OTHER PUBLICATIONS

California Code of Regulations, Section 1968.1, Title 13—Malfunction and Diagnostic System Requirements 1994 and Subsequent Model Year Passenger Cars, Light Duty Trucks, and Medium Duty Vehicles with Feedback Control Systems

(R) Environmental Protection Agency 40 CFR Part 86 Control of Air Pollution from New Motor Vehicles and New Motor Vehicle Engines; Regulations Requiring On-Board Diagnostic Systems on 1994 and Later Model Year Light-Duty Vehicles and Light-Duty Trucks

3. Application—The requirements contained in this document apply to all test equipment (e.g., handheld scan tool, PC based test equipment, inspection and maintenance equipment, etc.) that will be used to access the OBD II functions supported in vehicles.

Only tools passing the conformance test(s) specified in this document may claim or advertise that they meet or exceed the requirements of this document.

Nothing in this document precludes the inclusion of additional capabilities or functions in test equipment.

(R) *4. Diagnostic Terms, Definitions, and Acronyms*—SAE J1930 is hereby referenced as the basis for all such terms in this document.

(R) *5. Required Functions*—The following are the basic functions that the OBD II Scan Tool is required to support or provide:

a. Automatic hands-off determination of the communication interface used
b. Obtaining and displaying the status and results of vehicle on-board diagnostic evaluations
c. Obtaining and displaying OBD II emissions related diagnostic trouble codes (DTCs)
d. Obtaining and displaying OBD II emissions related current data
e. Obtaining and displaying OBD II emissions related freeze frame data
f. Clearing the storage of OBD II emissions related diagnostic trouble codes, OBD II emissions related freeze frame data storage and OBD II emissions related diagnostic tests status
g. Ability to perform Expanded Diagnostic Protocol functions as described in SAE J2205
h. Obtaining and displaying OBD II emissions related test parameters and results as described in SAE J1979
i. Provide a user manual and/or help facility

6. Vehicle Interface—The following specifies the minimum vehicle interfaces to be supported by an OBD II Scan Tool.

(R) 6.1 Communication Data Link and Physical Layers—The OBD II Scan Tool must be able to communicate with vehicle control modules using the communication interfaces as described as follows. The OBD II Scan Tool must perform the communications required to support the State of California requirements referenced in the introduction to this document. SAE J2205 describes a set of functions and communication criteria.

(R) 6.1.1 SAE J1850 RECOMMENDED PRACTICE CLASS B DATA COMMUNICATION NETWORK INTERFACE—SAE J1850 describes two sets of data link and physical layers for a class B vehicle serial multiplex bus network. The OBD II Scan Tool must support both SAE J1850 protocols in a manner that is transparent to the user.

(R) 6.1.2 ISO 9141-2:1994(E) ROAD VEHICLES—DIAGNOSTIC SYSTEMS—CARB REQUIREMENTS FOR INTERCHANGE OF DIGITAL INFORMATION—ISO 9141-2 describes the physical and data link layers of a vehicle serial diagnostic bus.

The following specifications clarify and, if in conflict with ISO 9141-2, override any related specifications in ISO 9141-2:

a. The maximum sink current to be supported by the OBD II Scan Tool is 100 mA

b. The range for all tests performed relative to ISO 7637 is -1.0 to +40.0 V

c. The minimum bus idle period before the tool shall transmit an address shall be 300 ms

ISO 9141-2 specifies a time within which a module(s) that has successfully been initialized must receive a message or the module(s) will return to the address mode. Unless the OBD II Scan Tool user has indicated he/she wishes to terminate communication, once a module(s) has successfully been initialized, the OBD II Scan Tool must automatically send a message, to be identified as the idle message, before this time can elapse. Any use of any response received due to the idle message is left to the discretion of the scan tool manufacturer.

The SAE J1979 mode 1 PID 0 request message is the recommended idle message.

6.2 Connector—The OBD II Scan Tool must use a male SAE J1962 Diagnostic Connector to mate with the female SAE J1962 Diagnostic Connector required in vehicles. The OBD II Scan Tool must support the standard pin assignments defined in SAE J1962. The electrical interface in the OBD II Scan Tool for the manufacturer discretionary pin assignments shall be effectively open circuit as a default condition or state.

6.3 Messages—SAE J1979 describes the request messages to be sent by the OBD II Scan Tool to the vehicle and the response messages to be sent by the vehicle to the OBD II Scan Tool in order to perform the services required by OBD II.

(R) 6.4 Expanded Diagnostic Protocol—The OBD II Scan Tool must allow the user to enter and send vehicle specific messages defined and supplied in motor vehicle manufacturer documents and display the related response messages, as defined in SAE J2178.

6.5 Automatic Hands-off Determination of the Communication Interface Used in a Given Vehicle

(R) 6.5.1 GENERAL—While there are three types of communication interfaces that could be used to access the OBD II functions in a given vehicle (i.e., SAE J1850 41.6 Kbps PWM, SAE J1850 10.4 Kbps VPW and ISO 9141-2), only one is allowed to be used in any one vehicle to access all supported OBD II functions.

When connected to a vehicle and/or when the OBD II support is selected where such a selection is necessary, the OBD II Scan Tool will automatically attempt to determine which of the possible communication interfaces is being used in the vehicle to support OBD II related functions. The tool will continue to try to determine which interface is being used until it is successful in doing so. No user input will be required, nor allowed, to determine the appropriate interface.

Indications or messages will be displayed during this process informing the user that initialization is taking place and, if all interface types have been tested and none is responding properly to the request for OBD II services, the OBD II Scan Tool must indicate to the user:

a. To verify that the ignition is on.

(R) b. To check the Emissions Label or vehicle service information to verify that the vehicle is OBD II equipped.

(R) c. To check that the tool is connected to the vehicle correctly.

(R) If the ignition is on and the vehicle emissions label or service information indicates the vehicle is OBD II equipped, then there is a Data Link fault.

6.5.2 INITIALIZATION DETAILS—Only the following steps may be used by an OBD II Scan Tool to attempt to determine the type of communications interface used in a given vehicle to support OBD II functions.

a. Test for SAE J1850 41.6 Kbps PWM

(1) Step 1—Enable the SAE J1850 41.6 Kbps PWM interface

(2) Step 2—Send a mode 1 PID 0 request message

(3) Step 3—If a mode 1 PID 0 response message is received for the J1850 41.6 Kbps PWM is the type of interface used in a vehicle for OBD II support.

(R) b. Test for SAE J1850 10.4 Kbps VPW

(1) Step 1—Enable the SAE J1850 10.4 Kbps VPW interface

(2) Step 2—Send a mode 1 PID 0 request message

(3) Step 3—If a mode 1 PID 0 response message is received for the J1850 10.4 Kbps VPW is the type of interface used in a vehicle for OBD II support.

c. Test for ISO 9141 CARB (R

(1) Step 1—Enable the ISO 9141-2 interface

(2) Step 2—If the initialization sequence defined in ISO 9141-2 is completed successfully, then ISO 9141-2 is the type of interface used in a vehicle for OBD II support. (R

The previous tests may be performed in any order and where possible may be performed in parallel.

The mode 1 PID 0 request and response messages are defined in SAE J1979.

SAE J1850 defines the requirements of SAE J1850 interfaces.

ISO 9141-2 defines the requirements of an ISO 9141-2 interface.

6.6 On-Board Diagnostic Evaluations

(R) 6.6.1 COMPLETED ON-BOARD SYSTEM READINESS TESTS—Immediately the initial communications are established, the OBD II Scan Tool shall obtain the status of the on-board system readiness tests. If any tests have not been completed, the OBD II Scan Tool shall indicate to the user, "Not all support on-board system readiness tests have been completed," or equivalent. The OBD II Scan Tool shall also allow the user to identify which readiness tests (if any) have not been completed.

6.6.2 SUPPORTED ON-BOARD SYSTEM READINESS TESTS—The OBD II Scan Tool must be capable of indicating to the user which of the tests defined by SAE J1979 mode 1 PID 1 data bytes 4 and 5 are supported and which are complete.

6.6.3 MALFUNCTION INDICATOR LIGHT—The OBD II Scan Tool must be capable of indicating if the MIL has been commanded ON and if so, by which module or modules.

6.7 Use of SAE J2381 Universal Interface for OBD II Scan Tools—The OBD II Scan Tool shall use the interface described in SAE J2381, or an equivalent, as the interface to vehicles.

(R) 6.8 Handling of No Response From Vehicle—Vehicle modules may be required to request messages from the OBD II Scan Tool because of normal communication of a request message or because the module does not support the request message. If a response is not received, the scan tool should:

a. First, retransmit the request message

b. Second, if still no response is received, transmit a mode 1 PID 0 request message, in order to determine if communication with the vehicle is currently possible, and if the data desired is available.

c. Third, if a mode 1 PID 0 response is received, transmit other messages, if available, to determine if the data desired is supported by the vehicle.

d. Lastly, if the previous steps fail then as appropriate indicate to the user that communication with the vehicle, the module or for the information the user has selected cannot be performed.

(R) 6.9 Connections to the Vehicle in Addition to the SAE J1962 Diagnostic Connector—Where connections are made between external equipment and the vehicle in addition to connections made between the user external equipment and the vehicle using the SAE J1962 Diagnostic Connector, any ground circuits must conform to the requirements of the Chassis Ground Circuit in the SAE J1962 connector. The intent of this requirement is to maintain the isolation between the vehicle ground and the signal ground in external equipment.

7. *System Intervention Capability*

(R) 7.1 Obtain and Display OBD II Emissions Related Diagnostic Trouble Codes—The OBD II Scan Tool must be capable of obtaining, converting, and displaying all of the OBD II emissions related diagnostic trouble codes from a vehicle that can be transmitted by a response to a SAE J1979 request. Either the diagnostic trouble code, its descriptive text, or both must be displayed. Diagnostic Trouble Codes and their descriptive text are defined in SAE J2012. When diagnostic trouble code data are selected for display, the OBD II Scan Tool will continuously request of the vehicle its diagnostic trouble code data and display the data received in the corresponding response messages.

7.2 Obtain and Display OBD II Emissions Related Current Data, Freeze Frame Data, and Test Parameters and Results—The OBD II Scan Tool must be capable of obtaining, converting, and displaying (a) OBD II emissions related current data, (b) OBD II emissions related freeze frame data, and (c) test parameters and results data as described in SAE J1979. SAE J1979

details what data is available, the messages to be used to request the data, the messages to be used to return the data, the conversion values for the data and the format to be used to display the data.

When current data items are selected for display, the OBD II Scan Tool will continuously request of the vehicle the data to be displayed and will display the data received in the corresponding response messages. When freeze frame or test parameters and results are selected for display, the OBD II Scan Tool does not need to continuously request and display those items.

(R) Where applicable, the OBD II Scan Tool must indicate whether a test limit is a high limit or a low limit. Where applicable, the display of test results must also show the test id and component id.

(R) Data from the vehicle may indicate which items are supported, in which case this information should be made available to the user by the OBD II Scan Tool. The OBD II Scan Tool shall also allow users to specify requests for modes, parameters, test ids, etc. irrespective of whether the vehicle has indicated support for such items.

7.3 Responses from Multiple Modules---The OBD II Scan Tool must be capable of interfacing with a vehicle in which multiple modules may be used to support OBD II requirements.

The OBD II Scan Tool must alert the user when multiple modules respond to the same request.

The OBD II Scan Tool must advise/alert the user when multiple modules respond with different values for the same data item.

The OBD II Scan Tool must provide the user with the ability to select for display as separate display items the responses received from multiple modules for the same data item.

7.4 Code Clearing---The OBD II Scan Tool must be capable of sending a request to clear OBD II emissions related diagnostic trouble codes, OBD II emissions related freeze frame data and OBD II emissions related diagnostic tests status information. The OBD II Scan Tool must require the user to validate a user's request to send this request before sending it (i.e., are you sure?).

8. General Characteristics

8.1 Display---The OBD II Scan Tool must be capable of displaying simultaneously at least two items of OBD II emissions related current data items, OBD II emissions related freeze-frame data items, or OBD II emissions related diagnostic trouble codes.

A list of the OBD II emissions related current data and freeze frame data items, their parameter ids, data resolution and data conversion information, units and display formats is provided in SAE J1979. The display units shall be the Standard International (SI) and English units as specified in SAE J1979. A user shall be able to select between English and SI values. The unit conversions specified in SAE J1979 shall be used.

The display of each OBD II emissions related current data or freeze frame data shall include the following:

a. Data value
b. Data Parameter id or name
c. The module id of the module that supplied the data

The display of each OBD II emissions related diagnostic trouble code shall include the module id of the module that supplied the code.

As a minimum the data values of two data items must be displayed simultaneously. A display of the parameter ids of the data items and the ids of the modules that supplied the data items must be easily accessible if not displayed with the data values.

(R) The units of measure associated with the data items displayed must either be displayed with the data values, easily accessible on another display, or otherwise readily available to the user (e.g., on the tester body, as a part of the tester on a cheat sheet, etc.). Having this information available in a user's manual separate from the body of the tool does not satisfy this requirement.

The display must be capable of showing alphanumeric characters.

8.2 User Input---The OBD II Scan Tool must include some form of user input that would allow the user to:

a. Select between the basic functions required by OBD II (i.e., display current data, display freeze frame data, display trouble codes, clear emissions related data, and display test parameters and results),
b. Select for simultaneous display at least two items of any one of the following:
   (1) OBD II emissions related current data
   (2) OBD II emissions related diagnostic trouble codes
   (3) OBD II emissions related freeze frame data
   (4) OBD II emissions related test parameters and results

   Responses from multiple modules to requests for a current data item or a freeze frame data item are treated as separate data items for selection and display purposes.

(R) c. To verify a request to clear and/or reset OBD II emissions related diagnostic information as defined by SAE J1979.
d. Enter and send Expanded Diagnostic Protocol messages.

9. Power Requirements if Powered by the Vehicle Through the SAE J1962 Diagnostic Connector

a. Voltage
   (1) Must operate normally within a range of 8.0 to 18.0 V D.C.
   (2) Must survive a steady-state voltage of up to 24.0 V D.C. for at least 10.0 min
   (3) Must survive a steady-state reverse voltage of up to 24.0 V D.C. for at least 10 min
b. Current
   (1) Must not draw more than 4.0 A at 14.4 V D.C.

10. Electromagnetic Compatibility (EMC)---The tool must not interfere with the normal operation of vehicle modules.

The normal operation of the tool must be immune to conducted and radiated emissions present in a service environment and when connected to a vehicle.

The tool must be immune to reasonable levels of Electrostatic Discharge (ESD).

EMC and ESD measurements and limits will be according to SAE J1113.

11. Conformance Testing

11.1 General---Conformance testing defines the tests required to be passed in order for tools to be typed approved as "SAE J1978 JUN94 OBD II COMPATIBLE" or "CONFORMS TO SAE J1978 JUN94." Tools that do not pass these tests are not to be so labeled. Validation of conformance test is the responsibility of the Scan Tool manufacturer and the Scan Tool Manufacturer may elect to self-certify.

The tests in this section must be performed successfully five consecutive times in order to be considered passed.

Three examples of at least production intent level tools must pass all these tests in order for a given version of tool hardware and software to be considered passed.

Any changes to the hardware or software used in a tool for the functions described in this document will require a retest of these tests or an explanation from the tool manufacturer as to why the change should not require a retest. Where an explanation is submitted in lieu of a retest due to a change, the organization originally performing these tests will determine whether the explanation is acceptable or whether a retest is required. Reasonable normal engineering criteria will be used when determining whether to accept an explanation.

The Scan Tool Manufacturer shall make available to the buying public:

a. The methods used to make these tests
b. The results of the tests
c. Clear indication of the versions of hardware and software that conform (i.e., labeled as conforming to or are compatible with the requirements of SAE J1978 OBD II Scan Tool or other labeling to that effect).

(R) Both proper and improper response messages will be employed during these tests. Improper responses are those that have incorrect first, second, or third bytes of the header, an incorrect mode, an incorrect PID id, an incorrect length of the response message, or with an incorrect CRC or CS. The tool must ignore all improper response messages and perform as if no response was received.

Situations involving multiple modules responding to a single request, single modules responding with multiple responses to a single request, and multiple modules responding with multiple responses to a single request will be tested.

The interval between the end of the request message and the beginning of the response message(s) will be varied from 0 ms up to the delay required to show a no response indication on the OBD II Scan Tool. The delay that causes the no response indication will be compared to the value defined in SAE J1979.

The format, content, and order of messages transmitted on the SAE J1850 and ISO 9141-2 buses will be observed and reviewed for correctness.

The ability to obtain and report the results of the on-board system readiness tests shall be verified. The ability to report which tests the vehicle supports and which have been completed shall be verified.

The requirements described in 11.3 through 11.7 (inclusive) shall be verified on each protocol specified in 5.1.

When performing these tests, observation of the indications and displays provided to the user and the signals on the SAE J1850 (bus +) and (bus -) lines and the ISO 9141-2 K and L lines will be the criteria for proper performance.

(R) These tests will be executed in an environment of 25 °C ± 3 °C and between 30% and 80% relative humidity ±5%.

The hardware and software used in the OBD II Scan Tool version being tested must be identified.

11.2 Determine OBD II Communication Type—Items to be tested:

Automatic hands-off determination of interface type.

That it is automatic when the SAE J1962 connector is plugged into its mating connector in the vehicle and/or OBD II support is selected, where such a selection is necessary.

That a test of all OBD II communication interfaces is performed at least once per scan.

That the scan of all interfaces continues until successful or until terminated by the user.

That some indication is provided to the user that the scan of interfaces is being performed.

That a failure to successfully find an OBD II interface during a scan of all the possible interfaces is indicated to the user at the completion of each and every scan.

That when an OBD II interface is successfully found, the tool automatically prompts the user for function selection.

That the tool provides and uses the facilities and/or messages defined in SAE J2201 (or equivalent), SAE J1979, ISO 9141-2 and SAE J1850, and SAE J2012.

That the tool does not exceed the polling rates specified in SAE J1979.

That the tool provides the proper bias for the K and L lines as specified in ISO 9141-2.

That the tool performs the initialization tests according to 6.5.2 and indicates the information according to 6.5.1.

(R) The interface determination tests will be performed: (a) with no modules available, (b) with an ISO 9141-2 module available, (c) with a SAE J1850 41.6 Kbps PWM module available, and (d) with a SAE J1850 10.4 Kbps VPW module available.

11.3 On-Board System Readiness Tests—Item to be tested:

That the tool automatically requests and reports the results of the supported on-board system readiness tests.

11.4 Select Functions—Items to be tested:

a. That the tool supports the functions described in Section 5.

b. That the user is able to move back and forth between these functions.

The criteria for successfully passing this test is to be able to easily move back and forth between all functions and observe the results. The support provided should allow the user to easily move between functions.

11.5 Select and Display Items—Items to be tested:

a. That the user is able to select and display simultaneously at least two items from any one of:
   (1) Available Diagnostic Trouble Codes
   (2) Current data items
   (3) Available freeze frame data items
   (4) Test parameters and results

b. That the module ids and the parameter ids or PID names associated with all the items mentioned previously can also be displayed either (a) simultaneously with the displayed items or (b) in some alternate method (printed material, etc.)

c. That the units of measure information associated with all the possible current data items and freeze frame data items is easily available either as a part of the data display, displayed separately, or otherwise available on, or with the tool body itself.

d. That the tool is able to handle multiple responses from the same module due to one request.

e. That the tool is able to handle responses from multiple modules due to one request.

f. That the tool is able to handle multiple responses from multiple modules due to one request.

g. That the tool alerts the user that responses from multiple modules due to one request were received. Responses from multiple modules to a request are to be made available to the user as separate items for display.

h. That the tool advises/alerts the user that different responses from multiple modules due to one request were received.

The criteria for successfully passing this test is to select back and forth between all the items and observe the results. The support provided should allow the user to easily move between display items.

11.6 Verify Requests to Clear Codes—Items to be tested:

a. That the selection of the Clear Codes function incorporates a request to the user to verify the request.

b. That both yes and no responses to the request to the user to verify the selection of the Clear Codes function are processed appropriately.

This test should involve situations where there are some DTCs to clear and other situations where there are no DTCs to clear. When making this test, the presence or absence of DTCs must be verified both before and after the Clear Codes function is selected.

11.7 General Diagnostic Communication Tests—When performing tests involving diagnostic messages, tests are to be made of the tool's ability to handle an immediate response, a slow response and a response delayed longer than the maximum allowed in SAE J1979.

The tool should be able to process all responses that are received within the maximum time allowed by SAE J1979 and indicate a no response condition to the user when the response is delayed longer than the maximum allowed by SAE J1979.

The tool must support the transmission of its node address as an in-frame-response during the transmission of any response messages from modules on a SAE J1850 bus and must be able to handle both the presence and the absence of an in-frame-response during the tool's transmission of request messages.

11.8 Expanded Diagnostic Protocol—Item to be tested:

a. That the user is reasonably able to enter Expanded Diagnostic Protocol (EDP) input and that the OBD II Scan Tool correctly executes the entered EDP input.

11.9 Capacitance and Impedance at the SAE J1962 Connector—Item to be tested:

a. That the capacitance and impedance of the OBD II Scan Tool, connecting cables and the male SAE J1962 connector, as seen at the connector, are within the limits defined in SAE J1850 and ISO 9141-2.

Measurement of these parameters will be made by the testing agency at their discretion following generally acceptable engineering practices.

11.10 Operating Voltage and Current Draw—Items to be tested:

a. That the OBD II Scan Tool will correctly operate throughout the voltage range specified in Section 9 of this document and will not require more than the maximum current specified in Section 9 of this document.

b. That the tool will survive the use of supply voltages of up to the maximum survival voltage and survival reverse voltage specified in Section 9 of this document.

During other conformance tests, the voltage supplied to the OBD II Scan Tool is to be varied throughout the specified range and the results observed. Also the current draw is to be compared with the limit specified.

11.11 Protocol Check—Items to be tested:

a. That all the request messages defined by SAE J1979 are properly and appropriately used by the OBD II Scan Tool.

b. That the OBD II Scan Tool is able to correctly process all forms of response messages defined by SAE J1979.

(R) c. That the OBD II Scan Tool is able to perform the previously mentioned, the SAE J1850 and ISO 9141-2 buses.

11.12 Alphanumeric Display—Item to be tested:

a. That the OBD II Scan Tool is able to display alphanumeric characters.

The results of the previous tests will be observed to determine the ability of the OBD II Scan Tool to display alphanumeric characters.

11.13 User Manual and Help Facility—Items to be tested:

a. That a useful user manual and/or HELP facility is provided with the OBD II Scan Tool.

b. That the user manual and/or HELP facility includes:
   (1) SAE J1979 definitions
   (2) How to select the functions
   (3) How to select items for simultaneous display
   (4) How to determine the PID id, item name, and module id of data returned for display
   (5) How to verify the selection of the Clear Codes function
(R) (6) How to obtain and display OBD II emissions related test parameters and results as described in SAE J1979
   (7) How multiple responses from one request is indicated
   (8) How different responses to the same request is indicated
   (9) What current and freeze frame data items are available through OBD II
   (10) How to enter requests for the Expanded Diagnostic Protocol and interpret the results

(R) The OBD II Scan Tool will be tested for a HELP facility and/or the availability and coverage of a user manual.

Report of the SAE Vehicle E/E Systems Diagnostic Standards Committee approved December 1991, revised June 1994, and completely revised July 1996. Rationale statements available.

Foreword—This document describes the implementation of the Diagnostic Test Modes necessary to meet California On-Board Diagnostic (OBD II) and Federal On-Board Diagnostic (OBD) requirements for emission related test data. This document is one of several prepared by task forces of the SAE E/E Diagnostics Committee in order to satisfy the proposed regulations. The development of these recommended practices has been coordinated so that they are compatible with each other and with the legislation. Other documents necessary in addition to this document are:

SAE J1930—E/E Systems Diagnostic Terms, Definitions, Abbreviations, and Acronyms
SAE J1962—Diagnostic Connector
SAE J1978—OBD II Scan Tool
SAE J2012—Recommended Format and Messages for Diagnostic Trouble Codes

In addition, the diagnostic data communication link to be utilized with these recommended practices is specified by the regulation to be as specified in one of the following documents:

SAE J1850—Class B Data Communication Network Interface
ISO 9141-2:1994(E)—Road vehicles—Diagnostic systems—CARB requirements for interchange of digital information

TABLE OF CONTENTS

1. Scope
2. References
2.1 Applicable Documents
2.1.1 SAE Publications
2.1.2 ISO Publications
2.1.3 California ARB Publications
2.1.4 Federal EPA Publications
3. Definitions
3.1 Absolute Throttle Position Sensor
3.2 Bank
3.3 Base Fuel Schedule
3.4 Calculated Load Value
3.5 Continuous Monitoring
3.6 Fuel Trim
4. Technical Requirements
4.1 Diagnostic Test Mode General Conditions
4.1.1 Multiple Responses to a Single Data Request
4.1.2 Response Time
4.1.3 Minimum Time Between Requests From Scan Tool
4.1.4 Data Not Available
4.1.5 Maximum Values
4.2 Diagnostic Message Format
4.2.1 Addressing Method
4.2.2 Maximum Message Length
4.2.3 Diagnostic Message Format
4.2.4 Header Bytes
4.2.5 Data Bytes
4.2.6 Non-Data Bytes Included in Diagnostic Messages With SAE J1850
4.2.7 Non-Data Bytes Included in Diagnostic Messages With ISO 9141-2
4.2.8 Bit Position Convention
4.3 Allowance for Expansion and Enhanced Diagnostic Test Modes
4.4 Format of Data to be Displayed
5. Test Modes
5.1 Mode $01—Request Current Powertrain Diagnostic Data
5.1.1 Functional Description
5.1.2 Message Data Bytes
5.2 Mode $02—Request Powertrain Freeze Frame Data
5.2.1 Functional Description
5.2.2 Message Data Bytes
5.3 PIDs for Modes $01 and $02
5.4 Mode $03—Request Emission-Related Powertrain Diagnostic Trouble Codes
5.4.1 Functional Description
5.4.2 Message Data Bytes
5.4.3 Powertrain Diagnostic Trouble Code Example
5.5 Mode $04—Clear/Reset Emission-Related Diagnostic Information
5.5.1 Functional Description
5.5.2 Message Data Bytes
5.6 Mode $05—Request Oxygen Sensor Monitoring Test Results
5.6.1 Functional Description
5.6.2 Message Data Bytes
5.7 Mode $06—Request On-Board Monitoring Test Results
5.7.1 Functional Description
5.7.2 Message Data Bytes
5.7.3 Message Example
5.8 Mode $07—Request On-Board Monitoring Test Results
5.8.1 Functional Description
5.8.2 Message Data Bytes
5.9 Mode $08—Request Control of On-Board System, Test, or Component
5.9.1 Functional Description
5.9.2 Message Data Bytes
5.9.3 Test ID and Data Byte Descriptions

1. Scope—This SAE Recommended Practice defines diagnostic test modes, and request and response messages, necessary to be supported by vehicle manufacturers and test tools to meet the requirements of the California OBD II and Federal OBD regulations, which pertain to vehicle emission-related data only. These messages are intended to be used by any service tool capable of performing the mandated diagnostics.

In addition, capabilities are defined that are intended to meet other Federal and State regulations pertaining to related issues such as Inspection and Maintenance (I/M) and service information availability. This document is not considered a final authority for interpretation of the regulations, so the reader should determine the applicability of the capabilities defined in this document for their specific need.

Diagnostic Test Modes included in this document are:

a. Mode $01—Request Current Powertrain Diagnostic Data
   - Analog inputs and outputs
   - Digital inputs and outputs
   - System status information
   - Calculated values
b. Mode $02—Request Powertrain Freeze Frame Data
   - Analog inputs and outputs
   - Digital inputs and outputs
   - System status information
   - Calculated values
c. Mode $03—Request Emission-Related Powertrain Diagnostic Trouble Codes
d. Mode $04—Clear/Reset Emission-Related Diagnostic Information
e. Mode $05—Request Oxygen Sensor Monitoring Test Results
f. Mode $06—Request On-Board Monitoring Test Results for Non-Continuously Monitored Systems
g. Mode $07—Request On-Board Monitoring Test Results for Continuously Monitored Systems
h. Mode $08—Request Control of On-Board System, Test, or Component

For each test mode, this specification includes:

a. Functional descriptions of test mode
b. Request and response message formats

For some of the more complex test modes, an example of messages and an explanation of the interpretation of those messages is included.

2. References

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

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

SAE J1850—Class B Data Communication Network Interface

SAE J1930—E/E Systems Diagnostic Terms, Definitions, Abbreviations, and Acronyms

SAE J1962—Diagnostic Connector

SAE J1978—OBD II Scan Tool

SAE J2012—Recommended Format and Messages for Diagnostic Trouble Codes

SAE J2186—Diagnostic Data Link Security

SAE J2190—Enhanced E/E Diagnostic Test Modes

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

ISO 9141-2:1994(E)—Road vehicles—Diagnostic systems—CARB requirements for interchange of digital information

2.1.3 CALIFORNIA ARB DOCUMENTS—Available from California Air Resources Board, 9528 Telstar Avenue, El Monte, CA 91731.

California Code of Regulations, Title 13, Section 1968.1—Malfunction and Diagnostic System Requirements—1994 and Subsequent Model-Year Passenger Cars, Light-Duty Trucks, and Medium-Duty Vehicles and Engines (OBD II)

2.1.4 FEDERAL EPA DOCUMENTS—Available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

Environmental Protection Agency 40 CFR Part 86—Control of Air Pollution From New Motor Vehicles and New Motor Vehicle Engines; Regulations Requiring On-Board Diagnostic Systems on 1994 and Later Model Year Light-Duty Vehicles and Light-Duty Trucks

3. Definitions—Most terms for components and systems contained in this document are included in SAE J1930. This section includes additional definitions of terms not included in SAE J1930.

3.1 Absolute Throttle Position Sensor—This value is intended to represent the throttle opening. For systems where the output is proportional to the input voltage, this value is the percent of maximum input signal. For systems where the output is inversely proportional to the input voltage, this value is 100% minus the percent of maximum input signal. Throttle position at idle will usually indicate greater than 0%, and throttle position at wide open throttle will usually indicate less than 100%.

3.2 Bank—The group of cylinders which feed an oxygen sensor. Bank 1 contains the Number 1 cylinder.

3.3 Base Fuel Schedule—The fuel calibration schedule programmed into the Powertrain Control Module or PROM when manufactured or when updated by some off-board source, prior to any learned on-board correction.

3.4 Calculated Load Value—An indication of the current airflow divided by peak airflow, where peak airflow is corrected for altitude, if available. Mass airflow and barometric pressure sensors are not required for this calculation. This definition provides a unitless number that is not engine specific, and provides the service technician with an indication of the percent engine capacity that is being used (with wide open throttle as 100%).

$$CLV = \frac{\text{Current airflow}}{\text{Peak airflow (@ sea level)}} \times \frac{\text{Atmospheric pressure (@ sea level)}}{\text{Barometric pressure}} \times 100\% \quad \text{(Eq.1)}$$

3.5 Continuous Monitoring—Sampling at a rate no less than two samples per second.

3.6 Fuel Trim—Feedback adjustments to the base fuel schedule. Short-term fuel trim refers to dynamic or instantaneous adjustments. Long-term fuel trim refers to much more gradual adjustments to the fuel calibration schedule than short-term trim adjustments. These long-term adjustments compensate for vehicle differences and gradual changes that occur over time.

4. Technical Requirements

4.1 Diagnostic Test Mode General Conditions—These guidelines are necessary to ensure proper operation of both the test equipment and the vehicle during diagnostic procedures. Test equipment, when using messages defined in this document, should not affect normal operation of the emission control system.

4.1.1 MULTIPLE RESPONSES TO A SINGLE DATA REQUEST—The messages contained in this document are functional messages, which means the off-board test equipment will request data without knowledge of which module on the vehicle will respond. In some vehicles, multiple modules may respond with the information requested. In addition, a single module may send multiple responses to a single request. Any test device requesting information must, therefore, have provisions for receiving multiple responses.

4.1.2 RESPONSE TIME—For SAE J1850 network interfaces, the on-board systems should respond to a request within 100 ms of a request or a previous response. With multiple responses possible from a single request, this allows as much time as is necessary for all modules to access the data link and transmit their response(s). If there is no response within this time period, the tool can either assume no response will be received, or if a response has already been received, that no more responses will be received.

For ISO 9141-2 interfaces, response time requirements are specified in the ISO 9141-2 document.

4.1.3 MINIMUM TIME BETWEEN REQUESTS FROM SCAN TOOL—For SAE J1850 network interfaces, a tool should always wait for a response from the previous request, or "no response" timeout before sending another request. In no case should a request be sent less than 100 ms after the previous request.

For ISO 9141-2 interfaces, required times between requests are specified in the ISO 9141-2 document.

4.1.4 DATA NOT AVAILABLE—There are two conditions for which data is not available. One condition is that the test mode is not supported, and the other is that the test mode is supported, but data is not currently available.

There will be no reject message to a functional request if the request is not supported by the module. This prevents responses from all modules that do not support a test mode or a specific data value.

Some test modes are supported by a vehicle, but data may not always be available when requested. For Modes $05 and $06, if the test has not been run since test results were last cleared, or for Mode $02 if freeze frame data has not been stored, valid data will not be available. For these conditions, the manufacturer has the option to either not respond or to respond with data that is invalid. The functional descriptions for these test modes discuss the method to determine if data is valid.

4.1.5 MAXIMUM VALUES—If the data value exceeds the maximum value possible to be sent, the on-board system should send the maximum value possible ($FF or $FFFF). The tool should display the maximum value or an indication of data too high. This is not normally critical for real time diagnostics, but in the case of a misfire at 260 km/h with resulting freeze frame data stored, this will be very valuable diagnostic information.

4.2 Diagnostic Message Format

4.2.1 ADDRESSING METHOD—Functional addressing will be used for all generic Diagnostic Test Mode messages because the test tool does not know which system on the vehicle has the information that is needed.

4.2.2 MAXIMUM MESSAGE LENGTH—SAE J1850 defines required message elements and maximum message lengths that effectively limit the number of bytes that can be defined by this document to 12 bytes.

4.2.3 DIAGNOSTIC MESSAGE FORMAT—To conform to the SAE J1850 limitation on message length, diagnostic messages specified in this document begin with a three byte header, have a maximum of 7 data bytes, require ERR (error detection byte), and allow RSP (in-frame response byte), as shown in Figure 1.

Header Bytes (Hex)			Data Bytes								
Priority /Type	Target Address	Source Address	#1	#2	#3	#4	#5	#6	#7	ERR	RSP
Diagnostic Request at 10.4 Kbps (SAE J1850 and ISO 9141-2)											
68	6A	Fx	Maximum 7 Data Bytes							Yes	No
Diagnostic Response at 10.4 Kbps (SAE J1850 and ISO 9141-2)											
48	6B	adds	Maximum 7 Data Bytes							Yes	No
Diagnostic Request at 41.6 Kbps(SAE J1850)											
61	6A	Fx	Maximum 7 Data Bytes							Yes	Yes
Diagnostic Response at 41.6 Kbps (SAE J1850)											
41	6B	adds	Maximum 7 Data Bytes							Yes	Yes

FIGURE 1—DIAGNOSTIC MESSAGE FORMAT

4.2.4 HEADER BYTES—The first three bytes of all diagnostic messages are the header bytes. The value of the first header byte is dependent on the bit rate of the data link and the type of message, as shown in 4.2.3. The second byte has a value that depends on the type of message, either a request or a response. The third header byte is the physical address of the device sending the message.

Device address $F1 should be used for an OBD II Scan Tool, or any other tool that does not have a special reason to use another address. Other service tools should use addresses in the range from $F0 to $FD. The response to all request messages in this document will be independent of the address of the test equipment requesting the information.

Page 624 of 1656 OMEGA EXHIBIT 2037

Vehicle manufacturers should not use the SAE J1979 header bytes for any purpose other than diagnostic messages. When they are used, they must conform to this specification.

4.2.5 DATA BYTES—The maximum number of data bytes available to be specified in this document is 7. The first data byte following the header is the test mode, and the remaining 6 bytes vary depending on the specific test mode. Each unique diagnostic message defined in this document is a fixed length, although not all messages are the same length. For modes $01 and $02, message length is determined by Parameter Identification (PID). For Mode $05, message length is determined by Test ID. For other modes, the message length is determined by the mode. This enables the tools to check for proper message length, and to recognize the end of the message without waiting for possible additional data bytes.

4.2.6 NON-DATA BYTES INCLUDED IN DIAGNOSTIC MESSAGES WITH SAE J1850—All diagnostic messages will use a Cyclic Redundancy Check (CRC), as defined in SAE J1850, as the error detection (ER) byte.

In-frame response (RSF) is defined as optional in SAE J1850. For messages defined in this document, the RSF byte is required in all request and response messages at 41.6 Kbps, and is not allowed for messages at 10.4 Kbps.

SAE J1850 defines additional message elements that may be included in Diagnostic Messages. Use of these message elements is beyond the scope of this specification, but need to be considered when defining total diagnostic messages.

4.2.7 NON-DATA BYTES INCLUDED IN DIAGNOSTIC MESSAGES WITH ISO 9141-2—Messages will include a checksum, defined in ISO 9141-2, after the data bytes instead of the CRC used with SAE J1850.

There is no provision for an in-frame response in ISO 9141-2.

4.2.8 BIT POSITION CONVENTION—Some data byte values in this document include descriptions that are based on bit positions within the byte. The convention used in this document is that the Most Significant Bit (MSB) is referred to as "bit 7," and the Least Significant Bit (LSB) is referred to as "bit 0," as shown in Figure 2:

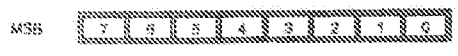


FIGURE 2—BIT POSITION WITHIN A DATA BYTE

4.3 Allowance for Expansion and Enhanced Diagnostic Test Modes—This document allows for the addition of Diagnostic Test Modes both as industry standards and manufacturer specific modes. Enhanced Diagnostic Test Modes are defined in a separate SAE document, J2190. That document reserves functional test modes $00 through $0F to be defined in SAE J1979 if needed to accommodate future legislated requirements.

4.4 Format of Data to be Displayed—The format of data to be displayed to the user of the data obtained with these test modes needs to be standardized so that vehicle manufacturers can write generic service information. The following table indicates the type of data and minimum requirements for format of the data. See Figure 3.

Data	Modes	Display Format
Device ID - source address of response	all	Hexadecimal (00 to FF)
Parameter ID (PID)	$01 & $02	Hexadecimal (00 to FF), description, or acronym (see table in 5.3)
Frame number	$02	Decimal (0 to 255)
Data values	$01 & $02	see table in 5.3
Diagnostic Trouble Codes	$03 & $07	"P," "B," "C," or "U" plus 4 digits and/or DTC definition - see SAE J2012
Test ID	$05, $06, & $08	Hexadecimal (00 to FF)
Test value and test limits	$05	Engineering units for Test IDs less than $80 (see 5.6.2) Decimal (0 to 255) for Test IDs greater than $80
Test value and test limits	$06	Decimal (0 to 65535)
Component ID	$05 (part of data byte #3)	Hexadecimal (00 to 7F)

FIGURE 3—FORMAT OF DATA TO BE DISPLAYED

5. Test Modes

5.1 Mode $01—Request Current Powertrain Diagnostic Data

5.1.1 FUNCTIONAL DESCRIPTION—The purpose of this mode is to allow access to current emission related data values, including analog inputs and outputs, digital inputs and outputs, and system status information. The request for information includes a Parameter Identification (PID) value that indicates to the on-board system the specific information requested. PID definitions, scaling information, and display formats are included in this document.

The on-board module will respond to this message by transmitting the requested data value last determined by the system. All data values returned for sensor readings will be actual readings, not default or substitute values used by the system because of a fault with that sensor.

Not all PIDs are applicable or supported by all systems. PID $00 is a bit-encoded PID that indicates, for each module, which PIDs that module supports. PID $00 must be supported by all modules that respond to a Mode $01 request as defined in this document, because diagnostic tools that conform to SAE J1978 use the presence of a response by the vehicle to this request to determine which protocol is supported for OBD II communications.

5.1.2 MESSAGE DATA BYTES—(See Figure 4.)

	Data Bytes (Hex)						
	#1	#2	#3	#4	#5	#6	#7
Request Current Powertrain Diagnostic Data							
Request Powertrain Diagnostic Data	01	PID					
Report Current Powertrain Diagnostic Data							
Report Powertrain Diagnostic Data	41	PID	data A	data B (opt)	data C (opt)	data D (opt)	

FIGURE 4—MESSAGE DATA BYTES

5.2 Mode $02—Request Powertrain Freeze Frame Data

5.2.1 FUNCTIONAL DESCRIPTION—The purpose of this mode is to allow access to emission related data values which were stored during the freeze frame required by OBD regulations. This mode allows expansion to meet manufacturer specific requirements not necessarily related to the required freeze frame, and not necessarily containing the same data values as the required freeze frame. The request for information includes a Parameter Identification (PID) value that indicates to the on-board system the specific information requested. PID definitions, scaling information, and display formats for the required freeze frame are included in this document.

The on-board module will respond to this message by transmitting the requested data value stored by the system. All data values returned for sensor readings will be actual readings, not default or substitute values used by the system because of a fault with that sensor.

Not all PIDs are applicable or supported by all systems. PID $00 is a bit-encoded PID that indicates, for each module, which PIDs that module supports. Therefore, PID $00 must be supported by all modules that respond to a Mode $02 request as defined in this document.

PID $02 is the DTC that caused the freeze frame data to be stored. If freeze frame data is not stored in the module, the system should report $00 00 as the DTC. Any data reported when the stored DTC is $00 00 may not be valid.

The frame number byte will indicate $00 for the OBD II mandated freeze frame data. Manufacturers may optionally save additional freeze frames and use this mode to obtain that data by specifying the freeze frame number in the request. If a manufacturer uses these additional freeze frames, they will be stored under conditions defined by the manufacturer, and contain data specified by the manufacturer.

5.2.2 MESSAGE DATA BYTES—(See Figure 5.)

	Data Bytes (Hex)						
	#1	#2	#3	#4	#5	#6	#7
Request Powertrain Freeze Frame Data							
Request Powertrain Freeze Frame Data	02	PID	frame no.				
Report Powertrain Freeze Frame Data (only valid if Mode $02 PID $02 DTC is not $00 00)							
Report Powertrain Freeze Frame Data	42	PID	frame no.	data A	data B (opt)	data C (opt)	data D (opt)

FIGURE 5—MESSAGE DATA BYTES

5.3 PIDs for Modes $01 and $02—(See Figure 6.)

Page 625 of 1656 OMEGA EXHIBIT 2037

5.4 Mode $03---Request Emission-Related Powertrain Diagnostic Trouble Codes

5.4.1 FUNCTIONAL DESCRIPTION---The purpose of this mode is to enable the off-board test device to obtain stored emission-related powertrain trouble codes. This should be a two step process for the test equipment.

a. Step 1---Send a Mode $01, PID $01 request to get the number of stored emission-related powertrain trouble codes from all modules that have this available. Each on-board module that has stored codes will respond with a message that includes the number of stored codes which that module can report. If a module capable of storing powertrain codes does not have stored codes, then that module shall respond with a message indicating zero codes are stored.

b. Step 2---Send a Mode $03 request for all stored emission-related powertrain codes. Each module that has codes stored will respond with one or more messages, each containing up to 3 codes. If no codes are stored in the module, then the module may not respond to this request.

If additional trouble codes are set between the time that the number of codes are reported by a module, and the stored codes are reported by a module, then the number of codes reported could exceed the number expected by the tool. In this case, the tool should repeat this cycle until the number of codes reported equals the number expected based on the Mode $01 response.

Diagnostic trouble codes are transmitted in two bytes of information for each code. The first two bits (high order) of the first byte for each code will be zeroes to indicate a powertrain code (refer to SAE J2012 for additional interpretation of this structure). The second two bits will indicate the first digit of the diagnostic code (0 through 3). The second nibble of the first byte and the entire second byte are the next three digits of the actual code reported as Binary Coded Decimal (BCD). A powertrain trouble code transmitted as $0143 should be displayed as P0143. (See Figure 7.)

If less than 3 trouble codes are reported, the response messages used to report diagnostic trouble codes should be padded with $00 to fill 7 data bytes. This maintains the required fixed message length for all messages.

If there are no diagnostic trouble codes to report, a response is allowed, but not required.

5.4.2 MESSAGE DATA BYTES---(See Figure 8.)

5.4.3 POWERTRAIN DIAGNOSTIC TROUBLE CODE EXAMPLE (ASSUME 10.4 KBPS)---(See Figure 9.)

5.5 Mode $04---Clear/Reset Emission-Related Diagnostic Information

5.5.1 FUNCTIONAL DESCRIPTION---The purpose of this mode is to provide a means for the external test device to command on-board modules to clear all emission-related diagnostic information. This includes:

a. Clear number of diagnostic trouble codes (Mode $01, PID $01)
b. Clear diagnostic trouble codes (Mode $03)
c. Clear trouble code for freeze frame data (Mode $01, PID $02)
d. Clear freeze frame data (Mode $02)
e. Clear oxygen sensor test data (Mode $05)
f. Reset status of system monitoring tests (Mode $01, PID $01)
g. Clear on-board monitoring test results (Mode $06 and $07)

Other manufacturer specific "clearing/resetting" actions may also occur in response to this request.

For safety and/or technical design reasons, some modules may not respond to this test mode under all conditions. All modules must respond to this test mode request with the ignition ON and with the engine not running. Modules that cannot perform this operation under other conditions, such as with the engine running, will ignore the request.

5.5.2 MESSAGE DATA BYTES---(See Figure 10.)

5.6 Mode $05---Request Oxygen Sensor Monitoring Test Results

5.6.1 FUNCTIONAL DESCRIPTION---The purpose of this mode is to allow access to the on-board oxygen sensor monitoring test results as required in OBD II regulations. Use of this mode is optional, depending on the method used by the vehicle manufacturer to comply with the requirement for oxygen sensor monitoring.

The request for test results includes a Test ID value that indicates the information requested. Test value definitions, scaling information, and display formats are included in this document.

Many methods may be used by different manufacturers to comply with this requirement. If data values are to be reported using these messages that are different from those predefined in this document, ranges of test values have been assigned that can be used that have standard units of measure. The tool can convert these values and display them in the proper units.

The on-board module will respond to this message by transmitting the requested test data last determined by the system.

Modes *		PID (HEX)	Description	Min (SI/Eng) or (SI/Hex)	Max (SI/Eng) or(SI/Hex)	SI (Metric) Scaling/bit and display	English Scaling/bit and display
$01	$02						
X	X	00	PIDs supported ($01-$20): Bytes BB CC DD Data A 7 6 5 4 3 2 1 0 $01 Data A 15 14 13 12 11 10 9 8 $02 . . . Data B 31 30 29 28 27 26 25 24 $04 . . . Data C 63 62 61 60 59 58 57 56 $20 Module responds with a message that contains 4 bytes of bit-encoded information, each bit indicating support or non-support of a PID where: 0 = PID not supported by this module 1 = PID supported by this module				
X		01	Data A - Number of emission-related powertrain trouble codes and MIL status: bits 0-6: Number of codes stored in this module bit 7: 0 = MIL not commanded ON by this module 1 = MIL commanded ON by this module Data B (bits 0 to 3) and Data C - Each bit indicates support or non-support of an on-board diagnostic evaluation: Data B covers continuous monitoring tests Data C covers non-continuous tests where: 0 = test not supported by this module 1 = test supported by this module Data B (bits 4 to 7) and Data D - Each bit indicates status of on-board diagnostic evaluation for this module, corresponding to tests included in Data B (bits 0 to 3) and Data C: 0 = test complete, or not applicable 1 = test not complete NOTE: Data B, bits 4 to 7, are required only for vehicles that do not support any non-continuous tests.				Data B: Bit Evaluation supported/status 0 Misfire monitoring supported 1 Fuel system monitoring supported 2 Comprehensive component monitoring supported 3 reserved (report as 0) 4 Misfire monitoring status 5 Fuel system monitoring status 6 Comprehensive component monitoring status 7 reserved (report as 0) Data C and Data D: Bit Evaluation supported/status 0 Catalyst monitoring 1 Heated catalyst monitoring 2 Evaporative system monitoring 3 Secondary air system monitoring 4 A/C system refrigerant monitoring 5 Oxygen sensor monitoring 6 Oxygen sensor heater monitoring 7 EGR system monitoring	

FIGURE 6---PIDS FOR MODES $01 AND $02

Modes *		PID (Hex)	Description	Min ($00) or ($0000)		Max ($FF) or ($FFFF)		SI (Metric) Scaling/bit and display	English Scaling/bit and display
$01	$02								
	X	02	Trouble code that caused required freeze frame data storage (2 byte value - $0000 indicates no freeze frame data)	00	00	FF	99	Pxxxx Bxxxx Cxxxx Uxxxx	
X	X	03	Data A: Fuel system 1 status Data B: Fuel system 2 status ($00 if not used) For each data byte, no more than one bit at a time can be set to a 1 to indicate the status of that bank, where: bit 0 = Open loop - has not yet satisfied conditions to go closed loop bit 1 = Closed loop - using oxygen sensor(s) as feedback for fuel control bit 2 = Open loop due to driving conditions (power enrichment, deceleration enleanment) bit 3 = Open loop due to detected system fault bit 4 = Closed loop, but fault with at least one oxygen sensor - may be using single oxygen sensor for fuel control bits 5-7 = reserved (report as 0)						
X	X	04	Calculated load value	0%		100%		100/255% xxx x%	
X	X	05	Engine coolant temperature	-40 °C		215 °C		1 °C with -40 °C offset xxx °C	xxx °F
X	X	06	Short term fuel trim - Bank 1 (use if only 1 fuel trim value)	-100.00% (lean)		99.22% (rich)		100/128% (0% at 128) xxx.x%	
X	X	07	Long term fuel trim - Bank 1	"		"		"	
X	X	08	Short term fuel trim - Bank 2	"		"		"	
X	X	09	Long term fuel trim - Bank 2	"		"		"	
X	X	0A	Fuel pressure (gage)	0 kPaG		765 kPaG		3 kPaG xxx kPaG	xx.x psig

FIGURE 6—PIDS FOR MODES $01 AND $02 (CONTINUED)

Modes *		PID (Hex)	Description	Min ($00) or ($0000)	Max ($FF) or ($FFFF)	SI (Metric) Scaling/bit and display	English Scaling/bit and display
$01	$02						
X	X	0B	Intake manifold absolute pressure	0 kPaA	255 kPaA	1 kPaA xxx kPaA	xx.x in.hg
X	X	0C	Engine RPM (2 byte value - high byte/low byte)	0 r/min	16,383.75 r/min	1/4 r/min xxxxx r/min	
X	X	0D	Vehicle speed	0 km/h	255 km/h	1 km/h xxx km/h	xxx MPH
X		0E	Ignition timing advance for #1 cylinder (not including mechanical advance)	-64 deg	+63.5 deg	1/2 deg with 0 deg at 128 xx.x deg	
X		0F	Intake air temperature	-40 °C	215 °C	1 °C with -40 °C offset xxx °C	xxx °F
X		10	Air flow rate from MAF sensor (2 byte value - high byte/low byte)	0 gm/s	655.35 gm/s	0.01 gm/s xxx.xx gm/s	xxxx.x lb/min
X		11	Absolute throttle position sensor	0%	100%	100/255% xxx x%	
X		12	Commanded secondary air status (8 supported, one, and only one bit at a time can be set to a 1) bit 0 1 = upstream of first catalytic converter bit 1 1 = downstream of first catalytic converter inlet bit 2 1 = atmosphere/off bits 3 - 7 = reserved (report as 0)				

FIGURE 6—PIDS FOR MODES $01 AND $02 (CONTINUED)

Modes *		PID (Hex)	Description	Min ($00) or ($0000)	Max ($FF) or ($FFFF)	SI (Metric) Scalings and display	English Scalings and display
$01	$02						
X or PID $1D		13	Location of oxygen sensors installed in the vehicle, where sensor 1 is closest to the engine. Each bit indicates the presence or absence of an oxygen sensor at each of the following locations. Multiple bits may be set to 1: Bit — Sensor location 0 — Bank 1 - Sensor 1 1 — Bank 1 - Sensor 2 2 — Bank 1 - Sensor 3 3 — Bank 1 - Sensor 4 4 — Bank 2 - Sensor 1 5 — Bank 2 - Sensor 2 6 — Bank 2 - Sensor 3 7 — Bank 2 - Sensor 4 where: 1 = sensor present at that location 0 = sensor not present at that location				
X		14 15 16 17 18 19 1A 1B	Bank 1 - Sensor 1 Bank 1 - Sensor 2 Bank 1 - Sensor 3 Bank 1 - Sensor 4 Bank 2 - Sensor 1 Bank 2 - Sensor 2 Bank 2 - Sensor 3 Bank 2 - Sensor 4 for each sensor: Data A - Oxygen sensor output voltage Data B - short term fuel trim associated with this sensor ($FF if the sensor is not used in the calculation)	0 V -100.00% (lean)	1.275 V 99.22% (rich)	This scaling assumes a nominal 1 V full scale oxygen sensor; any sensor with a different full scale value should be normalized to provide nominal full scale at $C8 (200 decimal). 0.005 V x.xxx V 100/128% (0% at 128) xxx.x%	
X		1C	OBD requirements to which vehicle is designed, where: $01 - OBD II (California ARB) $02 - OBD (Federal EPA) $03 - OBD and OBD II $04 - OBD I $05 - Not intended to meet any OBD requirements				
X or PID $13		1D	Location of oxygen sensors installed in the vehicle, where sensor 1 is closest to the engine. Each bit indicates the presence or absence of an oxygen sensor at each of the following locations. Multiple bits may be set to 1: Bit — Alternate sensor location 0 — Bank 1 - Sensor 1 1 — Bank 1 - Sensor 2 2 — Bank 2 - Sensor 1 3 — Bank 2 - Sensor 2 4 — Bank 3 - Sensor 1 5 — Bank 3 - Sensor 2 6 — Bank 4 - Sensor 1 7 — Bank 4 - Sensor 2 where: 1 = sensor present at that location 0 = sensor not present at that location				
X		1E	Auxiliary Input Status Bit 0: Power Take-Off (PTO) Status where: 0 = PTO not active 1 = PTO active Bits 1-7: reserved for future expansion (report as 0)				
		1F	Unused - reserved for future expansion				
X		20	PIDs supported ($21 - $40): Byte — Bit — PID Data A — 7 — $21 Data A — 6 — $22 ... Data B — 7 — $29 ... Data D — 0 — $40				
		21-3F	Reserved - to be specified in SAE J2190, if needed				
X		40	PIDs supported ($41 - $60):				
X		41-FF	Reserved for future expansion				

* NOTE—An "X" in the column under Modes $01 or $02 indicates that this value is included in OBD II regulations to be supported for this mode. Refer to the latest OBD II regulations to determine if each value is required to be supported on a given vehicle, or only required if available.
Although only vehicles meeting California ARB OBD II and Federal OBD regulations are required to support this document, manufacturers of other vehicles may choose to support this request for the convenience of service technicians.

FIGURE 6—PIDS FOR MODES $01 AND $02 (CONTINUED)

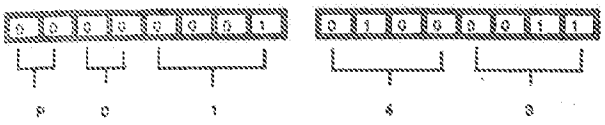


FIGURE 7—DIAGNOSTIC TROUBLE CODE ENCODING EXAMPLE

	Data Bytes (Hex)						
	#1	#2	#3	#4	#5	#6	#7
Request number of codes from all modules							
Request number of Powertrain DTC	01	01					
Report number of codes (each module)							
Report number of stored powertrain DTC	41	01	# DTC & MIL	Evaluation Support #1	Evaluation Support #2	Evaluation Status	
Request codes from all modules							
Request Powertrain DTC	01						
Report codes (each module)							
Report Powertrain DTC	43	Code #1 or 00 00		Code #2 or 00 00		Code #3 or 00 00	

NOTE—Refer to SAE J2012 for encoding method for trouble codes.

FIGURE 8—MESSAGE DATA BYTES

	Header Bytes (Hex)			Data Bytes (Hex)						
	F7	Tgt	Src	#1	#2	#3	#4	#5	#6	#7
Request Number of Powertrain DTC										
Request number of Powertrain DTC	68	6A	F1	01	01					
Report Number of Powertrain DTC										
Module 0B has 6 stored DTC	48	6B	0B	41	01	06	00	00	00	
Module C3 has 1 stored DTC	48	6B	C3	41	01	01	00	00	00	
Module 2B has 0 stored DTC	48	6B	2B	41	01	00	00	00	00	
Module 3E has 2 stored DTC and MIL ON	48	6B	3E	41	01	82	00	00	00	
Request All Stored Powertrain DTC										
Request Powertrain DTC	68	6A	F1	03						
Report All Stored Powertrain DTC										
Module 0B send codes P0143, P0148, & P0334	48	6B	0B	43	Code #1		Code #2		Code #3	
					01	43	01	48	03	34
Module C3 send code P0442	48	6B	C3	43	Code #1					
					04	42	00	00	00	00
Module 0B send codes P0327, P0331, & P0661	48	6B	0B	43	Code #4		Code #5		Code #6	
					03	27	03	31	06	61
Module 3E send codes P0112 & P0442	48	6B	3E	43	Code #1		Code #2			
					01	12	04	42	00	00

FIGURE 9—POWERTRAIN DIAGNOSTIC TROUBLE CODE EXAMPLE (ASSUME 10.4 Kbps)

	Data Bytes (Hex)						
	#1	#2	#3	#4	#5	#6	#7
Request to Clear/Reset Emission-Related Diagnostic Information							
Clear Powertrain DTC	04						
Report when Emission-Related Diagnostic Information is Reset							
Powertrain DTC cleared	44						

FIGURE 10—MESSAGE DATA BYTES

The operation of this diagnostic mode in the on-board module is different from Mode $01. Mode $01 reports data value(s) that are stored internally at a single, or multiple contiguous, locations in memory. Mode $05 can report data values that are stored in non-contiguous memory locations. Test results will be stored in RAM, and test limits, if the value is a calculated value, would normally be stored in ROM. Therefore, the on-board software has additional requirements to respond to this request than it does for Mode $01 requests.

Not all test values are applicable or supported by all vehicles. An optional feature of this test mode is for the on-board module to indicate which test IDs are supported. Test ID $00 is a bit-encoded value that indicates support for test IDs from $01 to $20. Test ID $20 indicates support for test IDs $21 through $40, etc. This is the same concept as used for PID support in test modes $01 and $02. If Test ID $00 is not supported, then the module does not use this feature to indicate test ID support.

5.6.2 MESSAGE DATA BYTES—(See Figures 11, 12, and 13.)

	Data Bytes (Hex)						
	#1	#2	#3	#4	#5	#6	#7
Request Oxygen Sensor Test Results							
Request Oxygen Sensor Test Results	05	Test ID	O2S #				
Report Oxygen Sensor Test ID Support - Optional (Test IDs $00, $20, $40, $60, $80, $A0, $C0, $E0)							
Report Oxygen Sensor Test ID Support	45	Test ID	O2S #	Support for the next 32 test IDs following the requested ID is indicated in data bytes #4 through #7			
Report Oxygen Sensor Test Results (All Test IDs That Don't Indicate Test ID Support Data is only valid if Mode $01 PID $01 indicates Oxygen sensor monitoring is supported and the test is complete)							
Report Oxygen Sensor Test Results	45	Test ID	O2S #	test value	min limit (note*)	max limit (note*)	

* NOTE—Report limits if value is a test result—not required for test constants, such as ID $01 to $04.

FIGURE 11—MESSAGE DATA BYTES

Results of latest mandated on-board oxygen sensor monitoring test.

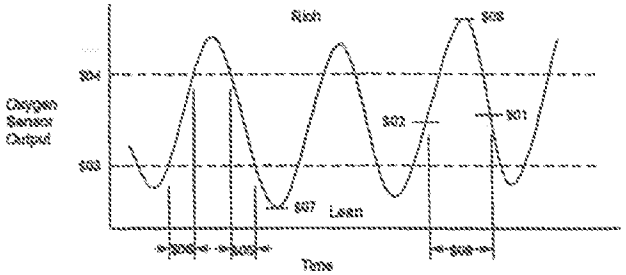


FIGURE 12—TEST ID VALUE EXAMPLE

Data Byte	Description
2	Which Test ID: $00 - Test ID's supported - optional ($01 to $20) $01 - Rich to lean sensor threshold voltage (constant) $02 - Lean to rich sensor threshold voltage (constant) $03 - Low sensor voltage for switch time calculation (constant) $04 - High sensor voltage for switch time calculation (constant) $05 - Rich to lean sensor switch time (calculated) $06 - Lean to rich sensor switch time (calculated) $07 - Minimum sensor voltage for test cycle (calculated) $08 - Maximum sensor voltage for test cycle (calculated) $09 - Time between sensor transitions (calculated) $0A - $1F - reserved $20 - Test IDs supported - optional ($21 to $40) $21 - $2F - values with units of time less than 1.02 s $30 - $3F - values with units of time less than 10.2 s $40 - Test IDs supported - optional ($41 to $60) $41 - $4F - values with units of voltage less than 1.275 V $50 - $5F - values with units of voltage less than 12.75 V $60 - Test IDs supported - optional ($61 to $80) $61 - $6F - values with units of Hertz less than 25.5 Hz $70 - $7F - values with units of counts less than 256 counts $80 - Test IDs supported - optional ($81 to $A0) $81 - $9F - manufacturer specific values/units $A0 - Test IDs supported - optional ($A1 to $C0) $A1 - $BF - manufacturer specific values/units $C0 - Test IDs supported - optional ($C1 to $E0) $C1 - $DF - manufacturer specific values/units $E0 - Test IDs supported - optional ($E1 to $FF) $E1 - $FF - manufacturer specific values/units

FIGURE 13—MESSAGE DATA BYTE DESCRIPTION

5.7 Mode $06—Request On-Board Monitoring Test Results for Non-Continuously Monitored Systems

5.7.1 FUNCTIONAL DESCRIPTION—The purpose of this test mode is to allow access to the results for on-board diagnostic monitoring tests of specific components/systems that are not continuously monitored. Examples are catalyst monitoring and the evaporative system monitoring.

The vehicle manufacturer is responsible to assign test IDs and component IDs for tests of different systems and components. Test results are requested by test ID. Only one test limit is included in a response message, but that limit could be either a minimum or a maximum limit. If both a minimum and maximum test limit are to be reported, then two response messages will be transmitted, in any order. The most significant bit of the "test limit type/component ID" byte will be used to indicate the test limit type.

This test mode can be used as an alternative to Mode $05 to report oxygen sensor test results.

5.7.2 MESSAGE DATA BYTES—(See Figure 14.)

5.7.3 MESSAGE EXAMPLE—(See Figure 15.)

5.8 Mode $07—Request On-Board Monitoring Test Results for Continuously Monitored Systems

5.8.1 FUNCTIONAL DESCRIPTION—The purpose of this mode is to enable the off-board test device to obtain test results for emission-related powertrain components/systems that are continuously monitored during normal driving conditions. The intended use of this data is to assist the service technician after a vehicle repair, and after clearing diagnostic information, by reporting test results after a single driving cycle. If the test failed during the driving cycle, the DTC associated with that test will be reported. Test results reported by this mode do not necessarily indicate a faulty component/system. If test results indicate a failure after additional driving, then the MIL will be illuminated and a DTC will be set and reported with Mode $03, indicating a faulty component/system.

Test results for these components/systems are reported in the same format as the diagnostic trouble codes in Test Mode $03—refer to the functional description for Mode $03.

If less than 3 DTC values are reported for failed tests, the response messages used to report the test results should be padded with $00 to fill 7 data bytes. This maintains the required fixed message length for all messages.

If there are no test failures to report, a response is allowed, but not required.

5.8.2 MESSAGE DATA BYTES—(See Figure 16.)

Data Byte	Description
3	Oxygen sensor location (one, and only one bit can be set to a 1): bit — Sensor location — Alternative sensor location 0 — Bank 1 - Sensor 1 — Bank 1 - Sensor 1 1 — Bank 1 - Sensor 2 — Bank 1 - Sensor 2 2 — Bank 1 - Sensor 3 — Bank 2 - Sensor 1 3 — Bank 1 - Sensor 4 — Bank 2 - Sensor 2 4 — Bank 2 - Sensor 1 — Bank 3 - Sensor 1 5 — Bank 2 - Sensor 2 — Bank 3 - Sensor 2 6 — Bank 2 - Sensor 3 — Bank 4 - Sensor 1 7 — Bank 2 - Sensor 4 — Bank 4 - Sensor 2 where: 1 = data requested for this sensor 0 = data not requested for this sensor
	The following 4 bytes define data bytes for Test IDs that indicate support of other Test IDs - optional (Bytes $20, $40, $60, $80, $A0, $C0, and $E0)
4	Support for Test ID, where 1 = support, 0 = non-support bit 7 - support for Test ID $01 bit 6 - support for Test ID $02 . . bit 0 - support for Test ID $08
5	Support for Test ID, where 1 = support, 0 = non-support: bit 7 - support for Test ID $09 bit 6 - support for Test ID $0A . . bit 0 - support for Test ID $10
6	Support for Test ID, where 1 = support, 0 = non-support: bit 7 - support for Test ID $11 bit 6 - support for Test ID $12 . . bit 0 - support for Test ID $18
7	Support for Test ID, where 1 = support, 0 = non-support bit 7 - support for Test ID $19 bit 6 - support for Test ID $1A . . bit 0 - support for Test ID $20
	The following 8 bytes define data bytes for Test IDs that report data values
8	Test ID: — Min ($00) — Max ($FF) — Scaling/bit Test ID $01 — 0 V — 1.275 V — 0.005 V Test ID $02 — 0 V — 1.275 V — 0.005 V Test ID $03 — 0 V — 1.275 V — 0.005 V Test ID $04 — 0 V — 1.275 V — 0.005 V Test ID $05 — 0 s — 1.02 s — 0.004 s Test ID $06 — 0 s — 1.02 s — 0.004 s Test IS $07 — 0 V — 1.275 V — 0.005 V Test ID $08 — 0 V — 1.275 V — 0.005 V Test ID $09 — 0 s — 10.2 s — 0.04 s Test ID $21 - $2F — 0 s — 1.02 s — 0.004 s Test ID $30 - $3F — 0 s — 10.2 s — 0.04 s Test ID $41 - $4F — 0 V — 1.275 V — 0.005 V Test ID $50 - $5F — 0 V — 12.75 V — 0.05 V Test ID $61 - $6F — 0 Hz — 25.5 Hz — 0.1 Hz Test ID $70 - $7F — 0 counts — 255 counts — 1 count
9	Minimum test limit (only for calculated test result) see Data Byte 84 for minimum value, maximum value, and scaling
10	Maximum test limit (only for calculated test result) see Data Byte 84 for minimum value, maximum value, and scaling

NOTE—Current oxygen sensors are nominally 1 V full scale. If an oxygen sensor is used with a different nominal output, the output voltage should be normalized to 1 V. Full scale should be reported as $C8 (decimal 200), which allows for reporting an overvoltage condition.

FIGURE 13—MESSAGE DATA BYTE DESCRIPTION (CONTINUED

	Data Bytes (Hex)						
	#1	#2	#3	#4	#5	#6	#7
Request Test Results							
Request Test Results	06	Test ID					
Report Test ID Support							
Report Test ID Support	46	Test ID	FF	Support for the next 32 test IDs following the requested ID for any component is indicated in data bytes #4 through #7			
Report Test Results - Multiple Responses may be Transmitted (Test IDs other than $00, $20, $40, $60, $80, $A0, $C0, $E0 Data is only valid if Mode $01 PID $01 indicates the monitoring test is supported and the test is complete)							
Report Test Results	46	Test ID	Test Limit Type & Component ID	test value		test limit	
				MSB	LSB	MSB	LSB

FIGURE 14—MESSAGE DATA BYTES

Data Byte	Description
3	Test ID $00 - Test IDs supported ($01 to $20) $01 - $1F - values defined by manufacturer $20 - Test IDs supported ($21 to $40) $21 - $3F - values defined by manufacturer $40 - Test IDs supported ($41 to $60) $41 - $5F - values defined by manufacturer $60 - Test IDs supported ($61 to $80) $61 - $7F - values defined by manufacturer $80 - Test IDs supported ($81 to $A0) $81 - $9F - values defined by manufacturer $A0 - Test IDs supported ($A1 to $C0) $A1 - $BF - values defined by manufacturer $C0 - Test IDs supported ($C1 to $E0) $C1 - $DF - values defined by manufacturer $E0 - Test IDs supported ($E1 to $FF) $E1 - $FF - values defined by manufacturer
4	bit 7: Most significant bit indicates type of test limit, where: 0 - test limit is maximum value - test fails if test value is greater than this value 1 - test limit is minimum value - test fails if test value is less than this value If the test result should be within a range of values, two messages will be returned, one with the maximum value and one with the minimum value bit 6 - bit 0: Component ID - manufacturer defined - necessary when multiple components or systems are present on the vehicle and have the same definition of test ID

FIGURE 14—MESSAGE DATA BYTES (CONTINUED)

Data Byte	Description
	The following 4 bytes define data bytes for Test IDs that indicate support of other Test IDs (Test IDs $00, $20, $40, $60, $80, $A0, $C0, and $E0)
4	Support for Test ID, where 1 = support, 0 = non-support: bit 7 - support for Test ID $01 bit 6 - support for Test ID $02 . . bit 0 - support for Test ID $08
5	Support for Test ID, where 1 = support, 0 = non-support: bit 7 - support for Test ID $09 bit 6 - support for Test ID $0A . . bit 0 - support for Test ID $10
6	Support for Test ID, where 1 = support, 0 = non-support: bit 7 - support for Test ID $11 bit 6 - support for Test ID $12 . . bit 0 - support for Test ID $18
7	Support for Test ID, where 1 = support, 0 = non-support: bit 7 - support for Test ID $19 bit 6 - support for Test ID $1A . . bit 0 - support for Test ID $20
	The following 4 bytes define data bytes for Test IDs that report data values (multiple response messages will be received if there are multiple components that support the same test ID and $FF is included as data byte #3 in the request message)
4-5	Test result (two byte value) - this value should be less than or equal to the test limit if most significant bit of data byte #3 is '0,' and should be greater than or equal to the test limit if most significant bit of data byte #3 is '1'
6-7	Test limit (two byte value)

FIGURE 14—MESSAGE DATA BYTES (CONTINUED)

5.8 Mode $08—Request Control of On-Board System, Test, or Component

5.8.1 FUNCTIONAL DESCRIPTION—The purpose of this mode is to enable the off-board test device to control the operation of an on-board system, test, or component.

The data bytes will be defined, if necessary, for each Test ID, and will be unique for each Test ID. If any data bytes are unused for any test, they should be filled with $00 to maintain a fixed message length.

a. Possible uses for these data bytes in the request message are:
   (1) Turn device ON
   (2) Turn device OFF
   (3) Cycle device for nn seconds
b. Possible uses for these data bytes in the response message are:
   (1) Report system status
   (2) Report test results

5.8.2 MESSAGE DATA BYTES—(See Figure 17.)

5.8.3 TEST ID AND DATA BYTE DESCRIPTIONS—(See Figure 18.)

Page 631 of 1656 OMEGA EXHIBIT 2037

	Data Bytes (Hex)						
	#1	#2	#3	#4	#5	#6	#7
Determine Test ID Support							
Request Test ID Support - ID in Hex	06	00					
Report Support for Test IDs 08, 10, 18, and 20	46	00	FF	00000100 =04	00000001 =01	00000000 =00	00000101 =05
Request Test ID Support	06	20					
Request Support for Test ID 40	46	20	FF	00000000 =00	00000000 =00	00000000 =00	00000001 =01
Request Test for ID Support	06	40					
Report Support for Test ID 60	46	40	FF	00000000 =00	00000000 =00	00000000 =00	00000001 =01
Request Test ID Support	06	60					
Report Support for Test ID 80	46	60	FF	00000000 =00	00000000 =00	00000000 00	00000001 =01
Request Test ID Support	06	80					
Report Support for Test ID A0	46	80	FF	00000000 =00	00000000 =00	00000000 =00	00000001 =01
Request Test ID Support	06	A0					
Report Support for Test ID A1 - no additional test IDs supported	46	A0	FF	10000000 =80	00000000 =00	00000000 =00	00000000 =00
Following messages indicate test results for component 01 smaller than the minimum							
Request Results for Test ID 08	06	08					
Report Results for component 01 - test value exceeds minimum - passed	46	08	81	test value		maximum test limit	
				3F	C4	16	00
Following messages indicate test results greater than the maximum for component ID 01 and less than the maximum for component 02							
Request Results for Test ID 10	06	10					
Report Results for component 01 - test value greater than maximum - failed	46	10	01	test value		maximum test limit	
				82	86	7F	FF
Report Results for component 02 - test value less than minimum - passed	46	10	02	test value		maximum test limit	
				06	81	88	A3
Following messages indicate test results for component 31 between the minimum and maximum limits							
Request Results for Test ID A1	06	A1					
Report Results for component 31 - test value greater than minimum - passed	46	A1	81	test value		maximum test limit	
				36	66	14	00
Report Results for component 31 - test value less than maximum - passed	46	A1	81	test value		maximum test limit	
				66	96	66	80

FIGURE 15—MESSAGE EXAMPLE

	Data Bytes (Hex)						
	#1	#2	#3	#4	#5	#6	#7
Request test results for continuously monitored systems							
Request test results	07						
Report test results for continuously monitored systems							
Report test results	47	Data #1 or 00-00	Data #2 or 00-00	Data #3 or 00-00			

FIGURE 16—MESSAGE DATA BYTES

	Data Bytes (Hex)						
	#1	#2	#3	#4	#5	#6	#7
Request control of on-board device							
Request control of on-board device	08	Test ID	Data A or $00	Data B or $00	Data C or $00	Data D or $00	Data E or $00
Report control of on-board device							
Report control of on-board device	48	Test ID	Data A or $00	Data B or $00	Data C or $00	Data D or $00	Data E or $00

FIGURE 17—MESSAGE DATA BYTES

Test ID (Hex)	Test ID and Data Byte Description
00	Test IDs supported ($01 to $20): Request: Data bytes A to E should be set to $00 Response: Data A - $00 Data B - Same as Data Byte #4 in Mode $06 Data C - Same as Data Byte #5 in Mode $06 Data D - Same as Data Byte #6 in Mode $06 Data E - Same as Data Byte #7 in Mode $06
01	Evaporative system leak test: Data bytes A to E should be set to $00 for request and response. If the conditions are not proper to run this test, the vehicle may either not respond to the request, or may respond with a manufacturer defined value as Data A which corresponds to the reason the test cannot be run. This test mode enables the conditions required to conduct an evaporative system leak test, but does not actually run the test. An example is to close a purge solenoid, preventing leakage if the system is pressurized. The vehicle manufacturer is responsible to determine the criteria to automatically stop the test (open the solenoid in the example), such as engine running, vehicle speed greater than zero, or exceeding a specified time period.
02 - FF	Reserved - to be defined by SAE

FIGURE 18—TEST ID AND DATA BYTE DESCRIPTIONS

RECOMMENDED PRACTICE FOR DIAGNOSTIC TROUBLE CODE DEFINITIONS—SAE J2012 JUL96 SAE Recommended Practice

Report of the SAE Vehicle E/E System Diagnostics Standards Committee approved March 1992, completely revised January 1994, and revised October 1994 and July 1996. Rationale statement available.

Foreword—Most automobile manufacturers are equipping at least a portion of their product line with some On-Board Diagnostic (OBD) capability. Although currently confined to California, emission regulations sponsored by the California Air Resources Board are requiring the implementation of OBD systems across all manufacturers' product lines of cars and light- and medium-duty trucks offered for sale in California, beginning with Model Year 1988. These systems are required to provide an indication to the service technician as to the general location of the diagnosed malfunction so that the proper service procedures are used to resolve the problem. In most cases, this information is provided through a numeric code.

Additional on-board diagnostic requirements have been defined by the OBD-II legislation in California and the Federal Clean Air Act. These requirements include the need for standardization of various parts of the system, including some of the Diagnostic Trouble Codes.

Currently, there is no uniformity in these numeric Diagnostic Trouble Codes (DTC) between manufacturers, and in some cases, even within the same manufacturer across different product lines. This document (SAE J2012) provides some recommended uniformity for these numeric codes. It further provides guidance for uniform messages associated with these codes.

The document itself (SAE J2012) is comprised of several sections addressing applicability, format structure, messages, and a few examples applying the recommendations of the document. The actual code assignments and messages are contained in four appendices attached to the document (Appendices A, B, C, and D). Codes and messages for Body systems are covered in Appendix A, Chassis systems in Appendix B, Powertrain systems in Appendix C, and Network Communication in Appendix D.

The recommended DTCs consist of a three-digit numeric code preceded by an alpha-numeric designator. The alpha-numeric designators are "B0," "B1," "B2," "B3," "C0," "C1," "C2," "C3," "P0," "P1," "P2," "P3," "U0," "U1," "U2," "U3," corresponding to four sets of Body, four sets of Chassis, four sets of Powertrain, and four sets of Network Communication Trouble Codes. The code structure itself is partially open-ended. A portion of the available numeric sequences (portions of "B0," "C0," "P0," and "U0") are reserved for uniform codes assigned by this or future updates of this document. Detailed specifications on the DTC format structure are covered in Section 3. Because of continued development in OBD systems and the flexibility of the partially open assignment structure, particular attention should be paid to the month and year of the publishing code contained in the full "J" number designation. It is possible that this document could be updated frequently, which would be reflected in the complete "J" number designation.

TABLE OF CONTENTS

1. Scope
1.1 Application
2. References
2.1 Applicable Documents
3. Definitions
4. Format Structure
4.1 Description
4.2 Core DTCs
4.3 Nonuniform DTC
4.4 Body System Groupings
4.5 Chassis System Groupings
4.6 Powertrain System Groupings
4.7 Network Communication Groupings
5. Messages
6. Examples
7. Change Requests
APPENDIX A BODY SYSTEM DIAGNOSTIC CODES
APPENDIX B CHASSIS SYSTEM DIAGNOSTIC CODES
APPENDIX C POWERTRAIN SYSTEM DIAGNOSTIC TROUBLE CODES
APPENDIX D NETWORK COMMUNICATION

1. Scope—This SAE Recommended Practice is applicable to all light-duty and medium-duty passenger vehicles and trucks with feedback fuel control system. Specific applications of this document include diagnostic, service and repair manuals, repair databases, and off-board readout devices.

This document focuses on a diagnostic code format and code messages for automotive electronic control systems.

The use and appropriate updating of this document is strongly encouraged; however, this document does not prohibit the use of additional codes for additional diagnostics.

1.1 Application—This document is applicable to all light-duty gasoline and diesel vehicles (LDV and LDDV), light-duty gasoline and diesel trucks (LDT and LDDT), and medium-duty gasoline vehicles (MDGV).

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

SAE J1979—E/E Diagnostic Test Modes

3. Definitions—Most circuit, component, or system Diagnostic Trouble Codes are defined by four basic categories: General Circuit Malfunction, Range/Performance Problem, Low or High Circuit Input. Most terms for components and systems contained in this document are included in SAE J1930. This section includes additional definitions of terms not included in SAE J1930.

While each manufacturer has the ability to define the specific DTCs to meet their specific controller algorithms, all DTC words must meet applicable SAE J1930.

3.1 GENERAL CIRCUIT MALFUNCTION—Fixed value or no response from the system. Manufacturers may choose to use this code in place of the dual High/Low (defined as follows) or use to indicate any other failure mode.

3.2 RANGE/PERFORMANCE—The circuit is functional but not in the normal operating range. May also be used to indicate stuck, erratic, intermittent, or skewed values indicating poor performance of a circuit, component, or system.

3.3 LOW INPUT—Circuit voltage, frequency, or other signal measured at the control module input terminal or pin that is at or near zero. This is measured with the external circuit, component, or system connected. The signal type

Page 633 of 1656 OMEGA EXHIBIT 2037

(voltage, frequency, etc.) shall be included in the message in place of the word "input."

3.4 HIGH INPUT—Circuit voltage, frequency, or other signal measured at the control module input terminal or pin that is at or near full scale for the particular signal being measured. This is measured with the external circuit, component, or system connected. The signal type (voltage, frequency, etc.) shall be included in the message in place of the word "input."

3.5 BANK—A specific group of cylinders sharing a common control sensor. Bank 1 contains cylinder #1. The next sensor in the same bank is number two, etc. If there is only one bank, use bank #1 DTCs and the word bank may be omitted. With a single "bank" system utilizing multiple sensors, use bank #1 DTCs identifying the sensors as #1, #2, #3 in order as they move further away from the cylinder(s).

3.6 SENSOR—If the sensors are numbered (i.e., Bank #1 Sensor #1) they follow the convention described previously in "Bank." If the sensors are indicated by a letter (i.e., A, B, C, etc.) this would be manufacturer defined. If a manufacturer uses only a single sensor then the number or letter may be omitted.

4. Format Structure

4.1 Description—The Diagnostic Trouble Code consists of an alpha-numeric designator, B0 — B3 for Body, C0 — C3 for Chassis, P0 — P3 for Powertrain, and U0 — U3 for Network Communication, followed by three digits. The assignment of the proper alpha designator should be determined by the controller into which the particular function being diagnosed is being integrated, or in the case of multiple controllers, the area most appropriate for that function. In most cases, the alpha designator will be implied since diagnostic information will be requested from a particular controller. In the cases where the source of the diagnostic information is not clear, the uppermost nibble of the two-byte code message as defined in SAE J1979 will define the source system as follows:

0000 - P0	- Powertrain codes SAE controlled
0001 - P1	- Powertrain codes Manufacturer controlled
0010 - P2	- Powertrain codes Reserved
0011 - P3	- Powertrain codes Reserved
0100 - C0	- Chassis codes SAE controlled
0101 - C1	- Chassis codes Manufacturer controlled
0110 - C2	- Chassis codes Manufacturer controlled
0111 - C3	- Chassis codes Reserved
1000 - B0	- Body codes SAE controlled
1001 - B1	- Body codes Manufacturer controlled
1010 - B2	- Body codes Manufacturer controlled
1011 - B3	- Body codes Reserved
1100 - U0	- Network Communication codes SAE controlled
1101 - U1	- Network Communication codes Manufacturer controlled
1110 - U2	- Network Communication codes Manufacturer controlled
1111 - U3	- Network Communication codes Reserved

Within each code class, the first of the three digits identifies a particular grouping of codes. These particular groupings each contain a series of 100 sequence numbers for particular code definitions.

Codes have been defined to indicate a suspected trouble or problem area and are intended to be used as a directive to the proper service procedure. To minimize service confusion, fault codes should not be used to indicate the absence of problems or the status of parts of the system (e.g., Powertrain System O.K., or MIL illuminated), but should be confined to indicate areas in need of service attention. The decision to illuminate the MIL for any DTC is manufacturer-specific based on their testing of how each system malfunction affects emissions.

4.2 Core DTCs—Core Diagnostic Trouble Codes are those codes where industry uniformity has been achieved. These codes were felt to be common enough across most manufacturers' applications that a common number and fault message could be assigned. All undefined numbers in each grouping of systems have been reserved for future growth. Although service procedures may differ widely amongst manufacturers, the fault being indicated is common enough to be assigned a particular fault code.

4.3 Nonuniform DTC—Areas within each alpha designator have been made available for nonuniform DTCs. These are fault codes that will not generally be used by a majority of the manufacturers due to basic system differences, implementation differences, or diagnostic strategy differences. Each vehicle manufacturer or supplier who designs and specifies diagnostic algorithms, software, and diagnostic trouble codes are strongly encouraged to remain consistent across their product line when assigning codes in the manufacturer controlled area. For Powertrain codes, the same groupings should be used as in the SAE controlled area, i.e., 100s and 200s for Fuel and Air Metering, 300s for Ignition System or Misfire, etc.

Code groupings for nonpowertrain codes will be defined at a later date.

4.4 Body System Groupings

4.4.1 - B0XXX SAE CONTROLLED
4.4.2 - B1XXX MANUFACTURER CONTROLLED
4.4.3 - B2XXX MANUFACTURER CONTROLLED
4.4.4 - B3XXX RESERVED

4.5 Chassis System Groupings

4.5.1 - C0XXX SAE CONTROLLED
4.5.2 - C1XXX MANUFACTURER CONTROLLED
4.5.3 - C2XXX MANUFACTURER CONTROLLED
4.5.4 - C3XXX RESERVED

4.6 Powertrain System Groupings

4.6.1 - P0XXX SAE CONTROLLED
- *4.6.1.1 - P01XX Fuel and Air Metering*
- *4.6.1.2 - P02XX Fuel and Air Metering*
- *4.6.1.3 - P03XX Ignition System or Misfire*
- *4.6.1.4 - P04XX Auxiliary Emission Controls*
- *4.6.1.5 - P05XX Vehicle Speed, Idle Control, and Auxiliary Inputs*
- *4.6.1.6 - P06XX Computer and Auxiliary Outputs*
- *4.6.1.7 - P07XX Transmission*
- *4.6.1.8 - P08XX Transmission*
- *4.6.1.9 - P09XX Reserved for SAE*
- *4.6.1.10 - P00XX Reserved for SAE*

4.6.2 - P1XXX MANUFACTURER CONTROLLED
- *4.6.2.1 - P11XX Fuel and Air Metering*
- *4.6.2.2 - P12XX Fuel and Air Metering*
- *4.6.2.3 - P13XX Ignition System or Misfire*
- *4.6.2.4 - P14XX Auxiliary Emission Controls*
- *4.6.2.5 - P15XX Vehicle Speed, Idle Control, and Auxiliary Inputs*
- *4.6.2.6 - P16XX Computer and Auxiliary Outputs*
- *4.6.2.7 - P17XX Transmission*
- *4.6.2.8 - P18XX Transmission*
- *4.6.2.9 - P19XX Category to be Determined by SAE*
- *4.6.2.10 - P10XX Category to be Determined by SAE*

4.6.3 - P2XXX SAE RESERVED
4.6.4 - P3XXX SAE RESERVED

4.7 Network Communication Groupings

4.7.1 - U0XXX SAE CONTROLLED
4.7.2 - U1XXX MANUFACTURER CONTROLLED
4.7.3 - U2XXX MANUFACTURER CONTROLLED
4.7.4 - U3XXX RESERVED

5. Messages—Each defined fault code has been assigned a message to indicate the circuit, component, or system area that was determined to be at fault. The messages are organized such that different messages related to a particular sensor or system are grouped together. In cases where there are various fault messages for different types of faults, the group also has a "generic" message as the first Code/Message of the group. A manufacturer has a choice when implementing diagnostics, based on the specific strategy and complexity of the diagnostic, whether to use one "generic" code for any fault of that circuit, component, or system or to use the more specific codes for better defining the type of fault that was detected. The manufacturer must determine what codes and messages best fit the diagnostics actually implemented. The intent is to have only one code stored for each fault detected.

Where messages are broken down into more specific fault descriptions for a circuit, component, or system, the manufacturer should choose the code most applicable to their diagnosable fault. The messages are intended to be somewhat general to allow manufacturers to use them as often as possible yet still not conflict with their specific repair procedures.

6. Examples—For manufacturers choosing to implement basic diagnostics that provide general fault information but depend on service procedures (Service Charts) and off-board techniques to isolate the problem, general circuit, component, and system codes would be used. If a fault is detected in the Throttle Position Sensor circuit, rather than burden the on-board system with determining the specific type of fault, a Code P0120 would be stored indicating some type of problem with that circuit, and the service procedure would then allow the technician to determine the type of fault and the specific location of the fault. On these types of systems, a shorted sensor input, an open sensor input, and even an out-of-range sensor input, would all set the same fault code.

Manufacturers choosing to allow the on-board diagnostics to better isolate the fault would not use the general fault code/message, but would use the more

Page 634 of 1656 OMEGA EXHIBIT 2037

specific codes/messages associated with the particular circuit, component, or system.

For example, in diagnosing a 5 V reference Throttle Position Sensor (TP Sensor), if the input signal at the Powertrain Control Module (PCM) is stuck at near 0 V, a manufacturer has the flexibility to select from either of two codes - P0120 (TP Sensor Circuit Malfunction) or P0122 (TP Sensor Low Input), depending on the manufacturer's diagnostic procedures. If the input signal at the PCM is stuck at near 5 V, a manufacturer has the flexibility to select from either of two codes - P0120 (TP Sensor Circuit Malfunction) or P0123 (TP Sensor High Input), depending on the manufacturer's diagnostic procedures. If the input signal at the PCM is stuck at 1.5 V at idle instead of the expected 1.0 V, the manufacturer has the flexibility to select from either of two codes - P0120 (TP Sensor Circuit Malfunction) or P0121 (TP Sensor Range/Performance), depending on the manufacturer's diagnostic procedures. The root cause of the higher than expected TP Sensor voltage may be either a faulty TP Sensor, corrosion in the TP Sensor connections or a misadjusted throttle plate. Identification of the root cause is done using the diagnostic procedures and is not implied by the DTC message, thus allowing the manufacturer the flexibility in assigning DTCs.

7. Change Requests—Any request for change or revision should be forwarded to:

SAE Headquarters
3001 Big Beaver
Suite 320
Troy, MI 48084
ATTN: J2012 Powertrain Committee Chairman

APPENDIX A
BODY SYSTEM DIAGNOSTIC CODES

FOR FUTURE DEFINITION

APPENDIX B
CHASSIS SYSTEM DIAGNOSTIC CODES

FOR FUTURE DEFINITION

APPENDIX C
POWERTRAIN SYSTEM DIAGNOSTIC TROUBLE CODES

C.1 Discussion—Following are the Recommended Industry Common Trouble Codes for the Powertrain Control System. These include systems that might be integrated into an electronic control module that would be used for controlling Engine functions, such as Fuel, Spark, Idle Speed, and Vehicle Speed (Cruise Control) as well as those for Transmission control. The fact that a code is recommended as a Common Industry Code does not imply that it is a Required Code (Legislated), an Emission Related Code, or that it indicates a fault that will cause the Malfunction Indicator Light to be illuminated.

C.1.1 P01XX Fuel and Air Metering

P0100	Mass or Volume Air Flow Circuit Malfunction	
P0101	Mass or Volume Air Flow Circuit Range/Performance Problem	
P0102	Mass or Volume Air Flow Circuit Low Input	
P0103	Mass or Volume Air Flow Circuit High Input	
P0104	Mass or Volume Air Flow Circuit Intermittent	
P0105	Manifold Absolute Pressure/Barometric Pressure Circuit Malfunction	
P0106	Manifold Absolute Pressure/Barometric Pressure Circuit Range/Performance Problem	
P0107	Manifold Absolute Pressure/Barometric Pressure Circuit Low Input	
P0108	Manifold Absolute Pressure/Barometric Pressure Circuit High Input	
P0109	Manifold Absolute Pressure/Barometric Pressure Circuit Intermittent	
P0110	Intake Air Temperature Circuit Malfunction	
P0111	Intake Air Temperature Circuit Range/Performance Problem	
P0112	Intake Air Temperature Circuit Low Input	
P0113	Intake Air Temperature Circuit High Input	
P0114	Intake Air Temperature Circuit Intermittent	
P0115	Engine Coolant Temperature Circuit Malfunction	
P0116	Engine Coolant Temperature Circuit Range/Performance Problem	
P0117	Engine Coolant Temperature Circuit Low Input	
P0118	Engine Coolant Temperature Circuit High Input	
P0119	Engine Coolant Temperature Circuit Intermittent	
P0120	Throttle/Pedal Position Sensor/Switch A Circuit Malfunction	
P0121	Throttle/Pedal Position Sensor/Switch A Circuit Range/Performance Problem	
P0122	Throttle/Pedal Position Sensor/Switch A Circuit Low Input	
P0123	Throttle/Pedal Position Sensor/Switch A Circuit High Input	
P0124	Throttle/Pedal Position Sensor/Switch A Circuit Intermittent	
P0125	Insufficient Coolant Temperature for Closed Loop Fuel Control	
P0126	Insufficient Coolant Temperature for Stable Operation	
P0130	O_2 Sensor Circuit Malfunction	(Bank 1[1] Sensor 1)
P0131	O_2 Sensor Circuit Low Voltage	(Bank 1[1] Sensor 1)
P0132	O_2 Sensor Circuit High Voltage	(Bank 1[1] Sensor 1)
P0133	O_2 Sensor Circuit Slow Response	(Bank 1[1] Sensor 1)
P0134	O_2 Sensor Circuit No Activity Detected	(Bank 1[1] Sensor 1)
P0135	O_2 Sensor Heater Circuit Malfunction	(Bank 1[1] Sensor 1)
P0136	O_2 Sensor Circuit Malfunction	(Bank 1[1] Sensor 2)
P0137	O_2 Sensor Circuit Low Voltage	(Bank 1[1] Sensor 2)
P0138	O_2 Sensor Circuit High Voltage	(Bank 1[1] Sensor 2)
P0139	O_2 Sensor Circuit Slow Response	(Bank 1[1] Sensor 2)
P0140	O_2 Sensor Circuit No Activity Detected	(Bank 1[1] Sensor 2)
P0141	O_2 Sensor Heater Circuit Malfunction	(Bank 1[1] Sensor 2)
P0142	O_2 Sensor Circuit Malfunction	(Bank 1[1] Sensor 3)
P0143	O_2 Sensor Circuit Low Voltage	(Bank 1[1] Sensor 3)
P0144	O_2 Sensor Circuit High Voltage	(Bank 1[1] Sensor 3)
P0145	O_2 Sensor Circuit Slow Response	(Bank 1[1] Sensor 3)
P0146	O_2 Sensor Circuit No Activity Detected	(Bank 1[1] Sensor 3)
P0147	O_2 Sensor Heater Circuit Malfunction	(Bank 1[1] Sensor 3)
P0150	O_2 Sensor Circuit Malfunction	(Bank 2 Sensor 1)
P0151	O_2 Sensor Circuit Low Voltage	(Bank 2 Sensor 1)
P0152	O_2 Sensor Circuit High Voltage	(Bank 2 Sensor 1)
P0153	O_2 Sensor Circuit Slow Response	(Bank 2 Sensor 1)
P0154	O_2 Sensor Circuit No Activity Detected	(Bank 2 Sensor 1)
P0155	O_2 Sensor Heater Circuit Malfunction	(Bank 2 Sensor 1)
P0156	O_2 Sensor Circuit Malfunction	(Bank 2 Sensor 2)
P0157	O_2 Sensor Circuit Low Voltage	(Bank 2 Sensor 2)
P0158	O_2 Sensor Circuit High Voltage	(Bank 2 Sensor 2)
P0159	O_2 Sensor Circuit Slow Response	(Bank 2 Sensor 2)
P0160	O_2 Sensor Circuit No Activity Detected	(Bank 2 Sensor 2)
P0161	O_2 Sensor Heater Circuit Malfunction	(Bank 2 Sensor 2)
P0162	O_2 Sensor Circuit Malfunction	(Bank 2 Sensor 3)
P0163	O_2 Sensor Circuit Low Voltage	(Bank 2 Sensor 3)
P0164	O_2 Sensor Circuit High Voltage	(Bank 2 Sensor 3)
P0165	O_2 Sensor Circuit Slow Response	(Bank 2 Sensor 3)
P0166	O_2 Sensor Circuit No Activity Detected	(Bank 2 Sensor 3)
P0167	O_2 Sensor Heater Circuit Malfunction	(Bank 2 Sensor 3)
P0170	Fuel Trim Malfunction	(Bank 1[1])
P0171	System too Lean	(Bank 1[1])
P0172	System too Rich	(Bank 1[1])
P0173	Fuel Trim Malfunction	(Bank 2)
P0174	System too Lean	(Bank 2)
P0175	System too Rich	(Bank 2)
P0176	Fuel Composition Sensor Circuit Malfunction	
P0177	Fuel Composition Sensor Circuit Range/Performance	
P0178	Fuel Composition Sensor Circuit Low Input	
P0179	Fuel Composition Sensor Circuit High Input	
P0180	Fuel Temperature Sensor A Circuit Malfunction	
P0181	Fuel Temperature Sensor A Circuit Range/Performance	
P0182	Fuel Temperature Sensor A Circuit Low Input	
P0183	Fuel Temperature Sensor A Circuit High Input	
P0184	Fuel Temperature Sensor A Circuit Intermittent	
P0185	Fuel Temperature Sensor B Circuit Malfunction	
P0186	Fuel Temperature Sensor B Circuit Range/Performance	
P0187	Fuel Temperature Sensor B Circuit Low Input	
P0188	Fuel Temperature Sensor B Circuit High Input	
P0189	Fuel Temperature Sensor B Circuit Intermittent	

[1] For systems with single O_2 sensors, use codes for Bank 1 sensor. Bank 1 contains cylinder #1. Sensor 1 is closest to the engine.

P0190 Fuel Rail Pressure Sensor Circuit Malfunction
P0191 Fuel Rail Pressure Sensor Circuit Range/Performance
P0192 Fuel Rail Pressure Sensor Circuit Low Input
P0193 Fuel Rail Pressure Sensor Circuit High Input
P0194 Fuel Rail Pressure Sensor Circuit Intermittent
P0195 Engine Oil Temperature Sensor Malfunction
P0196 Engine Oil Temperature Sensor Range/Performance
P0197 Engine Oil Temperature Sensor Low
P0198 Engine Oil Temperature Sensor High
P0199 Engine Oil Temperature Sensor Intermittent

C.1.2 P02XX Fuel and Air Metering

P0200 Injector Circuit Malfunction
P0201 Injector Circuit Malfunction - Cylinder 1
P0202 Injector Circuit Malfunction - Cylinder 2
P0203 Injector Circuit Malfunction - Cylinder 3
P0204 Injector Circuit Malfunction - Cylinder 4
P0205 Injector Circuit Malfunction - Cylinder 5
P0206 Injector Circuit Malfunction - Cylinder 6
P0207 Injector Circuit Malfunction - Cylinder 7
P0208 Injector Circuit Malfunction - Cylinder 8
P0209 Injector Circuit Malfunction - Cylinder 9
P0210 Injector Circuit Malfunction - Cylinder 10
P0211 Injector Circuit Malfunction - Cylinder 11
P0212 Injector Circuit Malfunction - Cylinder 12
P0213 Cold Start Injector 1 Malfunction
P0214 Cold Start Injector 2 Malfunction
P0215 Engine Shutoff Solenoid Malfunction
P0216 Injection Timing Control Circuit Malfunction
P0217 Engine Overtemp Condition
P0218 Transmission Over Temperature Condition
P0219 Engine Overspeed Condition
P0220 Throttle/Pedal Position Sensor/Switch B Circuit Malfunction
P0221 Throttle/Pedal Position Sensor/Switch B Circuit Range/Performance Problem
P0222 Throttle/Pedal Position Sensor/Switch B Circuit Low Input
P0223 Throttle/Pedal Position Sensor/Switch B Circuit High Input
P0224 Throttle/Pedal Position Sensor/Switch B Circuit Intermittent
P0225 Throttle/Pedal Position Sensor/Switch C Circuit Malfunction
P0226 Throttle/Pedal Position Sensor/Switch C Circuit Range/Performance Problem
P0227 Throttle/Pedal Position Sensor/Switch C Circuit Low Input
P0228 Throttle/Pedal Position Sensor/Switch C Circuit High Input
P0229 Throttle/Pedal Position Sensor/Switch C Circuit Intermittent
P0230 Fuel Pump Primary Circuit Malfunction
P0231 Fuel Pump Secondary Circuit Low
P0232 Fuel Pump Secondary Circuit High
P0233 Fuel Pump Secondary Circuit Intermittent
(R) P0234 Engine Overboost Condition
P0235 Turbocharger Boost Sensor A Circuit Malfunction
P0236 Turbocharger Boost Sensor A Circuit Range/Performance
P0237 Turbocharger Boost Sensor A Circuit Low
P0238 Turbocharger Boost Sensor A Circuit High
P0239 Turbocharger Boost Sensor B Circuit Malfunction
P0240 Turbocharger Boost Sensor B Circuit Range/Performance
P0241 Turbocharger Boost Sensor B Circuit Low
P0242 Turbocharger Boost Sensor B Circuit High
P0243 Turbocharger Wastegate Solenoid A Malfunction
P0244 Turbocharger Wastegate Solenoid A Range/Performance
P0245 Turbocharger Wastegate Solenoid A Low
P0246 Turbocharger Wastegate Solenoid A High
P0247 Turbocharger Wastegate Solenoid B Malfunction
P0248 Turbocharger Wastegate Solenoid B Range/Performance
P0249 Turbocharger Wastegate Solenoid B Low
P0250 Turbocharger Wastegate Solenoid B High
(R) P0251 Injection Pump Fuel Metering Control "A" Malfunction (Cam/Rotor/Injector)
(R) P0252 Injection Pump Fuel Metering Control "A" Range/Performance (Cam/Rotor/Injector)
(R) P0253 Injection Pump Fuel Metering Control "A" Low (Cam/Rotor/Injector)
(R) P0254 Injection Pump Fuel Metering Control "A" High (Cam/Rotor/Injector)
(R) P0255 Injection Pump Fuel Metering Control "A" Intermittent (Cam/Rotor/Injector)
(R) P0256 Injection Pump Fuel Metering Control "B" Malfunction (Cam/Rotor/Injector)
(R) P0257 Injection Pump Fuel Metering Control "B" Range/Performance (Cam/Rotor/Injector)
(R) P0258 Injection Pump Fuel Metering Control "B" Low (Cam/Rotor/Injector)
(R) P0259 Injection Pump Fuel Metering Control "B" High (Cam/Rotor/Injector)
(R) P0260 Injection Pump Fuel Metering Control "B" Intermittent (Cam/Rotor/Injector)
P0261 Cylinder 1 Injector Circuit Low
P0262 Cylinder 1 Injector Circuit High
P0263 Cylinder 1 Contribution/Balance Fault
P0264 Cylinder 2 Injector Circuit Low
P0265 Cylinder 2 Injector Circuit High
P0266 Cylinder 2 Contribution/Balance Fault
P0267 Cylinder 3 Injector Circuit Low
P0268 Cylinder 3 Injector Circuit High
P0269 Cylinder 3 Contribution/Balance Fault
P0270 Cylinder 4 Injector Circuit Low
P0271 Cylinder 4 Injector Circuit High
P0272 Cylinder 4 Contribution/Balance Fault
P0273 Cylinder 5 Injector Circuit Low
P0274 Cylinder 5 Injector Circuit High
P0275 Cylinder 5 Contribution/Balance Fault
P0276 Cylinder 6 Injector Circuit Low
P0277 Cylinder 6 Injector Circuit High
P0278 Cylinder 6 Contribution/Balance Fault
P0279 Cylinder 7 Injector Circuit Low
P0280 Cylinder 7 Injector Circuit High
P0281 Cylinder 7 Contribution/Balance Fault
P0282 Cylinder 8 Injector Circuit Low
P0283 Cylinder 8 Injector Circuit High
P0284 Cylinder 8 Contribution/Balance Fault
P0285 Cylinder 9 Injector Circuit Low
P0286 Cylinder 9 Injector Circuit High
P0287 Cylinder 9 Contribution/Balance Fault
P0288 Cylinder 10 Injector Circuit Low
P0289 Cylinder 10 Injector Circuit High
P0290 Cylinder 10 Contribution/Balance Fault
P0291 Cylinder 11 Injector Circuit Low
P0292 Cylinder 11 Injector Circuit High
P0293 Cylinder 11 Contribution/Balance Fault
P0294 Cylinder 12 Injector Circuit Low
P0295 Cylinder 12 Injector Circuit High
P0296 Cylinder 12 Contribution/Balance Fault

C.1.3 P03XX Ignition System or Misfire

P0300 Random/Multiple Cylinder Misfire Detected
P0301 Cylinder 1 Misfire Detected
P0302 Cylinder 2 Misfire Detected
P0303 Cylinder 3 Misfire Detected
P0304 Cylinder 4 Misfire Detected
P0305 Cylinder 5 Misfire Detected
P0306 Cylinder 6 Misfire Detected
P0307 Cylinder 7 Misfire Detected
P0308 Cylinder 8 Misfire Detected
P0309 Cylinder 9 Misfire Detected
P0310 Cylinder 10 Misfire Detected
P0311 Cylinder 11 Misfire Detected
P0312 Cylinder 12 Misfire Detected
P0320 Ignition/Distributor Engine Speed Input Circuit Malfunction
P0321 Ignition/Distributor Engine Speed Input Circuit Range/Performance
P0322 Ignition/Distributor Engine Speed Input Circuit No Signal
P0323 Ignition/Distributor Engine Speed Input Circuit Intermittent
P0325 Knock Sensor 1 Circuit Malfunction (Bank 1 or Single Sensor[2])
P0326
P0327
P0328
P0329
P0330
P0331
P0332
P0333
P0334
P0335
P0336
P0337
P0338
P0339
P0340
P0341
P0342
P0343
P0344
P0350
P0351
P0352
P0353
P0354
P0355
P0356
P0357
P0358
P0359
P0360
P0361
P0362
P0370
P0371
P0372
P0373
P0374
P0375
P0376
P0377
P0378
P0379
(R) P0380
P0381
(R) P0382
P0385
P0386
P0387
P0388
P0389
C.1.4 P
P0400
P0401
P0402
P0403
P0404
P0405
P0406
P0407
P0408
P0410
P0411

[2] Bank 1 contains cylinder #1.

[1] Bank 1

Knock Sensor 1 Circuit Range/Performance (Bank 1 or Single Sensor[3])
Knock Sensor 1 Circuit Low Input (Bank 1 or Single Sensor[3])
Knock Sensor 1 Circuit High Input (Bank 1 or Single Sensor[3])
Knock Sensor 1 Circuit Input Intermittent (Bank 1 or Single Sensor[3])
Knock Sensor 2 Circuit Malfunction (Bank 2)
Knock Sensor 2 Circuit Range/Performance (Bank 2)
Knock Sensor 2 Circuit Low Input (Bank 2)
Knock Sensor 2 Circuit High Input (Bank 2)
Knock Sensor 2 Circuit Input Intermittent (Bank 2)
(R) Crankshaft Position Sensor A Circuit Malfunction
(R) Crankshaft Position Sensor A Circuit Range/Performance
Crankshaft Position Sensor A Circuit Low Input
Crankshaft Position Sensor A Circuit High Input
Crankshaft Position Sensor A Circuit Intermittent
Camshaft Position Sensor Circuit Malfunction
Camshaft Position Sensor Circuit Range/Performance
Camshaft Position Sensor Circuit Low Input
Camshaft Position Sensor Circuit High Input
Camshaft Position Sensor Circuit Intermittent
Ignition Coil Primary/Secondary Circuit Malfunction
Ignition Coil A Primary/Secondary Circuit Malfunction
Ignition Coil B Primary/Secondary Circuit Malfunction
Ignition Coil C Primary/Secondary Circuit Malfunction
Ignition Coil D Primary/Secondary Circuit Malfunction
Ignition Coil E Primary/Secondary Circuit Malfunction
Ignition Coil F Primary/Secondary Circuit Malfunction
Ignition Coil G Primary/Secondary Circuit Malfunction
Ignition Coil H Primary/Secondary Circuit Malfunction
Ignition Coil I Primary/Secondary Circuit Malfunction
Ignition Coil J Primary/Secondary Circuit Malfunction
(R) Ignition Coil K Primary/Secondary Circuit Malfunction
Ignition Coil L Primary/Secondary Circuit Malfunction
(R) Timing Reference High Resolution Signal A Malfunction
Timing Reference High Resolution Signal A Too Many Pulses
(R) Timing Reference High Resolution Signal A Too Few Pulses
(R) Timing Reference High Resolution Signal A Intermittent/Erratic Pulses
Timing Reference High Resolution Signal A No Pulses
Timing Reference High Resolution Signal B Malfunction
Timing Reference High Resolution Signal B Too Many Pulses
Timing Reference High Resolution Signal B Too Few Pulses
Timing Reference High Resolution Signal B Intermittent/Erratic Pulses
Timing Reference High Resolution Signal B No Pulses
Glow Plug/Heater Circuit "A" Malfunction
Glow Plug/Heater Indicator Circuit Malfunction
Glow Plug/Heater Circuit "B" Malfunction
Crankshaft Position Sensor B Circuit Malfunction
Crankshaft Position Sensor B Circuit Range/Performance
Crankshaft Position Sensor B Circuit Low Input
Crankshaft Position Sensor B Circuit High Input
Crankshaft Position Sensor B Circuit Intermittent

P04XX Auxiliary Emission Controls

Exhaust Gas Recirculation Flow Malfunction
Exhaust Gas Recirculation Flow Insufficient Detected
Exhaust Gas Recirculation Flow Excessive Detected
Exhaust Gas Recirculation Circuit Malfunction
Exhaust Gas Recirculation Circuit Range/Performance
Exhaust Gas Recirculation Sensor A Circuit Low
Exhaust Gas Recirculation Sensor A Circuit High
Exhaust Gas Recirculation Sensor B Circuit Low
Exhaust Gas Recirculation Sensor B Circuit High
Secondary Air Injection System Malfunction
Secondary Air Injection System Incorrect Flow Detected
P0412 Secondary Air Injection System Switching Valve A Circuit Malfunction
P0413 Secondary Air Injection System Switching Valve A Circuit Open
P0414 Secondary Air Injection System Switching Valve A Circuit Shorted
P0415 Secondary Air Injection System Switching Valve B Circuit Malfunction
P0416 Secondary Air Injection System Switching Valve B Circuit Open
P0417 Secondary Air Injection System Switching Valve B Circuit Shorted
P0418 Secondary Air Injection System Relay "A" Circuit Malunction
P0419 Secondary Air Injection System Relay "B" Circuit Malfunction
P0420 Catalyst System Efficiency Below Threshold (Bank 1[4])
P0421 Warm Up Catalyst Efficiency Below Threshold (Bank 1[4])
P0422 Main Catalyst Efficiency Below Threshold (Bank 1[4])
P0423 Heated Catalyst Efficiency Below Threshold (Bank 1[4])
P0424 Heated Catalyst Temperature Below Threshold (Bank 1[4])
P0430 Catalyst System Efficiency Below Threshold (Bank 2)
P0431 Warm Up Catalyst Efficiency Below Threshold (Bank 2)
P0432 Main Catalyst Efficiency Below Threshold (Bank 2)
P0433 Heated Catalyst Efficiency Below Threshold (Bank 2)
P0434 Heated Catalyst Temperature Below Threshold (Bank 2)
P0440 Evaporative Emission Control System Malfunction
P0441 Evaporative Emission Control System Incorrect Purge Flow
P0442 Evaporative Emission Control System Leak Detected (small leak)
P0443 Evaporative Emission Control System Purge Control Valve Circuit Malfunction
P0444 Evaporative Emission Control System Purge Control Valve Circuit Open
P0445 Evaporative Emission Control System Purge Control Valve Circuit Shorted
P0446 Evaporative Emission Control System Vent Control Circuit Malfunction
P0447 Evaporative Emission Control System Vent Control Circuit Open
P0448 Evaporative Emission Control System Vent Control Circuit Shorted
P0449 Evaporative Emission Control System Vent Valve/Solenoid Circuit Malfunction
P0450 Evaporative Emission Control System Pressure Sensor Malfunction
P0451 Evaporative Emission Control System Pressure Sensor Range/Performance
P0452 Evaporative Emission Control System Pressure Sensor Low Input
P0453 Evaporative Emission Control System Pressure Sensor High Input
P0454 Evaporative Emission Control System Pressure Sensor Intermittent
P0455 Evaporative Emission Control System Leak Detected (gross leak)
P0460 Fuel Level Sensor Circuit Malfunction
P0461 Fuel Level Sensor Circuit Range/Performance
P0462 Fuel Level Sensor Circuit Low Input
P0463 Fuel Level Sensor Circuit High Input
P0464 Fuel Level Sensor Circuit Intermittent
P0465 Purge Flow Sensor Circuit Malfunction
P0466 Purge Flow Sensor Circuit Range/Performance
P0467 Purge Flow Sensor Circuit Low Input
P0468 Purge Flow Sensor Circuit High Input
P0469 Purge Flow Sensor Circuit Intermittent
P0470 Exhaust Pressure Sensor Malfunction
P0471 Exhaust Pressure Sensor Range/Performance
P0472 Exhaust Pressure Sensor Low
P0473 Exhaust Pressure Sensor High
P0474 Exhaust Pressure Sensor Intermittent

[3] Bank 1 contains cylinder #1.

[4] Bank 1 contains cylinder #1.

P0475 Exhaust Pressure Control Valve Malfunction
P0476 Exhaust Pressure Control Valve Range/Performance
P0477 Exhaust Pressure Control Valve Low
P0478 Exhaust Pressure Control Valve High
P0479 Exhaust Pressure Control Valve Intermittent
(R) P0480 Cooling Fan 1 Control Circuit Malfunction
(R) P0481 Cooling Fan 2 Control Circuit Malfunction
(R) P0482 Cooling Fan 3 Control Circuit Malfunction
(R) P0483 Cooling Fan Rationality Check Malfunction
(R) P0484 Cooling Fan Circuit Over Current
(R) P0485 Cooling Fan Power/Ground Circuit Malfunction

C.1.5 P05XX Vehicle Speed, Idle Control, and Auxiliary Inputs

P0500 Vehicle Speed Sensor Malfunction
P0501 Vehicle Speed Sensor Range/Performance
P0502 Vehicle Speed Sensor Circuit Low Input
P0503 Vehicle Speed Sensor Intermittent/Erratic/High
P0505 Idle Control System Malfunction
P0506 Idle Control System RPM Lower Than Expected
P0507 Idle Control System RPM Higher Than Expected
P0510 Closed Throttle Position Switch Malfunction
(R) P0520 Engine Oil Pressure Sensor/Switch Circuit Malfunction
(R) P0521 Engine Oil Pressure Sensor/Switch Range/Performance
(R) P0522 Engine Oil Pressure Sensor/Switch Low Voltage
(R) P0523 Engine Oil Pressure Sensor/Switch High Voltage
P0530 A/C Refrigerant Pressure Sensor Circuit Malfunction
P0531 A/C Refrigerant Pressure Sensor Circuit Range/Performance
P0532 A/C Refrigerant Pressure Sensor Circuit Low Input
P0533 A/C Refrigerant Pressure Sensor Circuit High Input
P0534 Air Conditioner Refrigerant Charge Loss
P0550 Power Steering Pressure Sensor Circuit Malfunction
P0551 Power Steering Pressure Sensor Circuit Range/Performance
P0552 Power Steering Pressure Sensor Circuit Low Input
P0553 Power Steering Pressure Sensor Circuit High Input
P0554 Power Steering Pressure Sensor Circuit Intermittent
P0560 System Voltage Malfunction
P0561 System Voltage Unstable
P0562 System Voltage Low
P0563 System Voltage High
P0565 Cruise Control On Signal Malfunction
P0566 Cruise Control Off Signal Malfunction
P0567 Cruise Control Resume Signal Malfunction
P0568 Cruise Control Set Signal Malfunction
P0569 Cruise Control Coast Signal Malfunction
P0570 Cruise Control Accel Signal Malfunction
P0571 Cruise Control/Brake Switch A Circuit Malfunction
P0572 Cruise Control/Brake Switch A Circuit Low
P0573 Cruise Control/Brake Switch A Circuit High
P0574 through P0580 Reserved for Cruise Codes

C.1.6 P06XX Computer and Auxiliary Outputs

P0600 Serial Communication Link Malfunction
P0601 Internal Control Module Memory Check Sum Error
P0602 Control Module Programming Error
P0603 Internal Control Module Keep Alive Memory (KAM) Error
P0604 Internal Control Module Random Access Memory (RAM) Error
P0605 Internal Control Module Read Only Memory (ROM) Error (Module Identification Defined by SAE J1979)
P0606 PCM Processor Fault
(R) P0608 Control Module VSS Output "A" Malfunction
(R) P0609 Control Module VSS Output "B" Malfunction
(R) P0620 Generator Control Circuit Malfunction
(R) P0621 Generator Lamp "L" Control Circuit Malfunction
(R) P0622 Generator Field "F" Control Circuit Malfunction
(R) P0650 Malfunction Indicator Lamp (MIL) Control Circuit Malfunction
(R) P0654 Engine RPM Output Circuit Malfunction
(R) P0655 Engine Hot Lamp Output Control Circuit Malfunction
(R) P0656 Fuel Level Output Circuit Malfunction

C.1.7 P07XX Transmission

P0700 Transmission Control System Malfunction
P0701 Transmission Control System Range/Performance
P0702 Transmission Control System Electrical
P0703 Torque Converter/Brake Switch B Circuit Malfunction
P0704 Clutch Switch Input Circuit Malfunction
P0705 Transmission Range Sensor Circuit Malfunction (PRNDL Input)
P0706 Transmission Range Sensor Circuit Range/Performance
P0707 Transmission Range Sensor Circuit Low Input
P0708 Transmission Range Sensor Circuit High Input
P0709 Transmission Range Sensor Circuit Intermittent
P0710 Transmission Fluid Temperature Sensor Circuit Malfunction
P0711 Transmission Fluid Temperature Sensor Circuit Range/Performance (R)
P0712 Transmission Fluid Temperature Sensor Circuit Low Input (R)
P0713 Transmission Fluid Temperature Sensor Circuit High Input
P0714 Transmission Fluid Temperature Sensor Circuit Intermittent
P0715 Input/Turbine Speed Sensor Circuit Malfunction
P0716 Input/Turbine Speed Sensor Circuit Range/Performance
P0717 Input/Turbine Speed Sensor Circuit No Signal
P0718 Input/Turbine Speed Sensor Circuit Intermittent
P0719 Torque Converter/Brake Switch B Circuit Low
P0720 Output Speed Sensor Circuit Malfunction
P0721 Output Speed Sensor Circuit Range/Performance
P0722 Output Speed Sensor Circuit No Signal
P0723 Output Speed Sensor Circuit Intermittent
P0724 Torque Converter/Brake Switch B Circuit High
P0725 Engine Speed Input Circuit Malfunction
P0726 Engine Speed Input Circuit Range/Performance
P0727 Engine Speed Input Circuit No Signal
P0728 Engine Speed Input Circuit Intermittent
P0730 Incorrect Gear Ratio
P0731 Gear 1 Incorrect Ratio
P0732 Gear 2 Incorrect Ratio
P0733 Gear 3 Incorrect Ratio
P0734 Gear 4 Incorrect Ratio
P0735 Gear 5 Incorrect Ratio
P0736 Reverse Incorrect Ratio
P0740 Torque Converter Clutch Circuit Malfunction
P0741 Torque Converter Clutch Circuit Performance or Stuck Off
P0742 Torque Converter Clutch Circuit Stuck On
P0743 Torque Converter Clutch Circuit Electrical
P0744 Torque Converter Clutch Circuit Intermittent
P0745 Pressure Control Solenoid Malfunction
P0746 Pressure Control Solenoid Performance or Stuck Off
P0747 Pressure Control Solenoid Stuck On
P0748 Pressure Control Solenoid Electrical
P0749 Pressure Control Solenoid Intermittent
P0750 Shift Solenoid A Malfunction
P0751 Shift Solenoid A Performance or Stuck Off
P0752 Shift Solenoid A Stuck On
P0753 Shift Solenoid A Electrical
P0754 Shift Solenoid A Intermittent
P0755 Shift Solenoid B Malfunction
P0756 Shift Solenoid B Performance or Stuck Off
P0757 Shift Solenoid B Stuck On
P0758 Shift Solenoid B Electrical
P0759 Shift Solenoid B Intermittent
P0760 Shift Solenoid C Malfunction
P0761 Shift Solenoid C Performance or Stuck Off
P0762 Shift Solenoid C Stuck On
P0763 Shift Solenoid C Electrical
P0764 Shift Solenoid C Intermittent
P0765 Shift Solenoid D Malfunction
P0766 Shift Solenoid D Performance or Stuck Off
P0767 Shift Solenoid D Stuck On
P0768 Shift Solenoid D Electrical
P0769 Shift Solenoid D Intermittent
P0770 Shift Solenoid E Malfunction
P0771 Shift Solenoid E Performance or Stuck Off
P0772 Shift Solenoid E Stuck On
P0773 Shift Solenoid E Electrical
P0774 Shift Solenoid E Intermittent
P0780 Shift Malfunction
P0781 1-2 Shift Malfunction
P0782 2-3 Shift Malfunction
P0783 3-4 Shift Malfunction
P0784 4-5 Shift Malfunction

	P0785	Shift/Timing Solenoid Malfunction
	P0786	Shift/Timing Solenoid Range/Performance
	P0787	Shift/Timing Solenoid Low
	P0788	Shift/Timing Solenoid High
	P0789	Shift/Timing Solenoid Intermittent
	P0790	Normal/Performance Switch Circuit Malfunction
(R)	C.1.8 P08XX Transmission	
(R)	P0801	Reverse Inhibit Control Circuit Malfunction
(R)	P0803	1-4 Upshift (Skip Shift) Solenoid Control Circuit Malfunction
(R)	P0804	1-4 Upshift (Skip Shift) Lamp Control Circuit Malfunction

APPENDIX D
NETWORK COMMUNICATION

FOR FUTURE DEFINITION

Report of the SAE Vehicle E/E Systems Diagnostics Standards Committee approved September 1991.

TABLE OF CONTENTS

1. Scope
2. References
2.1 Applicable Documents
2.1.1 SAE Publications
2.1.2 California Air Resources Board Regulations
2.2 Related Publications
2.2.1 SAE Publications
2.2.2 ISO Publications
3. Definitions
4. Technical Requirements
4.1 Data Link Security Strategy
4.2 Data Link Access Function Examples
4.2.1 Unsecured Read Data
4.2.2 Unsecured Service Alteration
4.2.3 Unsecured Permanent Alteration
4.2.4 Secured Read Data
4.2.5 Secured Service Alteration
4.2.6 Secured Permanent Alteration
4.3 Characteristics of Security
4.4 Functional Requirements

1. Scope—This SAE Recommended Practice establishes a uniform practice for protecting vehicle modules from "unauthorized" intrusion through a vehicle diagnostic data communication link. The security system represents a recommendation for motor vehicle manufacturers and provides flexibility for them to tailor their system to their specific needs. The vehicle modules addressed are those that are capable of having solid-state memory contents altered external to the electronic module through a diagnostic data communication link. Improper memory content alteration could potentially damage the electronics or other vehicle modules; risk the vehicle compliance to government legislated requirements, or risk the vehicle manufacturer's security interests. This document is intended to meet the "tampering protection" provisions of California Air Resources Board OBD II regulations and does not imply that other security measures are not required nor possible.

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.

J1978 MAR92 OBD II Scan Tool

2.1.2 California Air Resources Board Regulations—Available from Air Resources Board, Mobile Source Division, 9528 Telstar Avenue, El Monte, CA 91731.

Mail out #91-18 (OBD II)—Title 13, California Code of Regulations, Section 1968.1 Malfunction and Diagnostic System Requirements—1994 and Subsequent Model Year, Passenger Cars, Light Duty Trucks, and Medium-Duty vehicles with Feedback Fuel Control Systems.

2.2 Related Publications—The following publications are provided for information purposes only and are not a required part of this document.

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

J1850 AUG91—Class B Data Communication Network Interface
J1930 SEP91—Terms, Definitions, Abbreviations and Acronyms
J1979 DEC91—E/E Diagnostic Test Modes
2.2.1.1 The following publications are under development.
J1962 Draft Diagnostic Connector
J2012 Draft Format and Messages for Diagnostic Trouble Codes
J2190 Draft Enhanced E/E Diagnostic Test Modes
J2201 Draft Universal Interface for OBD II Scan Tool
J2205 Draft Expanded Diagnostic Protocol for OBD II Scan Tool

2.2.2 ISO Publications—Available from ANSI, 11 West 42nd Street, New York, NY 10036.

ISO/CD 9141-1 Road vehicles—Diagnostic systems—CARB requirements for April 1991 interchange of digital information.

3. Definitions

Standard Service Tool—A service tool providing basic emission related power train diagnostic tool functions, as required by CARB OBD II regulations. This service tool complies with SAE J1978 and is not necessarily limited to only OBD II functions.

Enhanced Service Tool—A service tool providing expanded emission related power train diagnostic functions in excess of the standard service tool and/or non-power train systems diagnostic tool functions.

Secured Service Tool—A service tool containing a feature for accessing secured data link functions. Use of this feature is limited by the vehicle manufacturer.

Unsecured Functions—Standard diagnostic functions that are provided by vehicle manufacturers. These are controlled and protected by the on-vehicle controller. The unsecured capability includes reprogramming of selected items for which the reprogrammer is liable.

Secured Functions—Manufacturer restricted functions that require "Unlocking" the on-vehicle controller to gain access. Typical functions include programming of vehicle emission systems.

Read Data Function—Operation which reads parameters and codes via the data link.

Service Alteration Function—Operation which temporarily alters the vehicle control system for the purpose of diagnosing the system's operation.

Permanent Alteration Function—Operation which permanently alters the operating characteristics of a vehicle module or system.

Seed—The data value sent from the on-board controller to the secured service tool.

Key—The data value sent from the secured service tool to the on-board controller.

4. Technical Requirements—Proper "Unlocking" of the controller shall be a prerequisite to access certain critical on-board controller functions; the only access to the on-board controller permitted while in a "Locked" mode is through the product-specific software. This permits the product-specific software to protect itself and the rest of the vehicle control system from unauthorized intrusion.

This document does not attempt to define capability or information that is under security; this is left to the vehicle manufacturer. The security system shall not prevent basic diagnostic communications between the external tool and the on-board controller.

4.1 Data Link Security Strategy—As shown in Table 1, the data link access of function is divided into two classifications: Unsecured and Secured. Each of these functions are subclassified as: Read Data, Service Alteration, and Permanent Alteration. These classifications are allocated to three types of service tools: Standard Tools, Enhanced Tools, and Secured Tools. The allocation of access classification by service tool type should provide for normal service capability of the vehicle and protect the vehicle from "unauthorized" intrusion of certain critical functions.

TABLE 1—SECURITY AUTHORITY ACCESS
DATA LINK ACCESS FUNCTION (REFER TO SECTION 4.2)

Service Tool Type	Unsecured Read Data (4.2.1)	Unsecured Service Alteration (4.2.2)	Unsecured Permanent Alteration (4.2.3)	Secured Read Data (4.2.4)	Secured Service Alteration (4.2.5)	Secured Permanent Alteration (4.2.6)
Standard (SAE J1978)	X	B	B	NA	NA	NA
Enhanced	X	E	E	NA	NA	NA
Secured	X	X	X	X	X	X

X —Function Allowed
NA —Not Allowed
B —Basic Diagnostic Capability Per Vehicle Manufacturer's Specification
E —Enhanced Diagnostic Capability

4.2 Data Link Access Function Examples

4.2.1 Unsecured Read Data
Read emission related data.
Read emission related trouble codes.

4.2.2 Unsecured Service Alteration
Cycle device on/off.
Substitute sensor value.

4.2.3 Unsecured Permanent Alteration
Change vehicle option/configuration data (i.e., tire size).
Reset electronic module.

4.2.4 Secured Read Data

Read keyless entry parameters.
Read executable code.

4.2.5 SECURED SERVICE ALTERATION

Vehicle assembly plant verification tests involving parameters not normally used in service.

4.2.6 SECURED PERMANENT ALTERATION

Alteration of a vehicle emission calibration.
Alteration of executable code.

4.3 **Characteristics of Security**—A special communications mode shall be provided to "Unlock" the on-board controllers which have secured or restricted functions. The security system is intended to make the emission related controller more immune to:

a. Unauthorized intrusion into the controller without full control of the product specific software.
b. Unauthorized alteration of the on-board control system or control parameters.

Disclosure of the "Seed/Key" relationship shall be limited to those persons, authorized by the vehicle manufacturer, who are responsible for the production of the secured service tool. The security system shall not prevent basic diagnostic or vehicle communications between external devices and the on-board controller.

There shall be three parameters which control the security access of the on-board controller:

a. The "Seed" and "Key" shall each be a minimum of 2 bytes in length. The relationship between the "Seed" and "Key" is the responsibility of the vehicle manufacturer. Multiple "Seed/Key" relationships may exist for access to different functions within a controller or systems within a vehicle.
b. The Delay Time (DT) shall be a minimum of 10 seconds; the vehicle manufacturer may specify an increased delay time to suit its specific requirements.
c. The Number of False Access Attempts (NFAA) shall be a maximum of two; the vehicle manufacturer may specify a reduced number of false attempts to suit its specific requirements. When the "Key" received by the controller is not correct, it shall be considered as a false access attempt; if access is rejected for any other reason, it shall not be considered a false access attempt.

4.4 **Functional Requirements**—Two request/response communication message pairs (Request #1/Response #1, Request #2/Response #2) shall be used to "Unlock" the on-board controller. The specific message content is not specified by this document and is the responsibility of the vehicle manufacturer.

a. Step 1—The external device shall request the on-board controller to "Unlock" itself by sending Request #1. The controller shall respond by sending a "Seed" using Response #1. A seed value of zero shall indicate that the controller is currently unlocked.
b. Step 2—The external device shall respond by returning a "Key" number back to the controller using Request #2. The controller shall compare this "Key" to one internally determined and issue Response #2.

If the two numbers agree, then the controller shall enable ("Unlock") the external device's access to secured communication modes.

If, upon "NFAA" attempts, the two keys do not compare (false attempt), then the controller shall insert the DT before allowing further attempts. The DT shall also be required at each controller power-on.

Three on-board controller responses shall be decoded by the external device:

a. Accept—The controller has "Unlocked" its access.
b. Invalid Key—The access attempt was rejected because the key was determined to be invalid by the controller; the access attempt was false.
c. Process Error—The access attempt was rejected for reasons other than receiving the wrong key; this shall not be counted as a false access attempt.

Termination of security access, "Locking" the product, shall result after any of the following conditions:

a. Each time the product is "powered up."
b. Upon commanding the product to a normal operational mode.
c. Conditions at the vehicle manufacturers discretion.

If an attempt is made to communicate with a "Locked" on-board controller and access a "Secured" function, the controller may return a special response indicating that the controller is "Locked" and cannot respond as requested.

OMEGA EXHIBIT 2037

Report of the SAE Vehicle E/E System Diagnostics Standards Committee approved June 1993.

TABLE OF CONTENTS

1. Scope
2. References
2.1.1 SAE Publications
2.1.2 ISO Publications
2.1.3 California ARB Documents
2.1.4 Federal EPA Documents
2.2 Definitions
3. Technical Requirements
3.1 Test Mode Values
3.2 Physical Addressing
3.3 Miscellaneous Requirements
3.3.1 Message Response Time
3.3.2 Automatic Return to Normal Operation
3.3.3 Diagnostic Message Length
3.3.4 Message Response
4. Test Modes
4.1 Modes $00 through $0F - Physically Addressed SAE J1979 Messages
4.2 Mode $10 - Initiate Diagnostic Operation
4.2.1 Functional Description
4.2.2 Message Data Bytes
4.3 Mode $11 - Request Module Reset
4.3.1 Functional Description
4.3.2 Message Data Bytes
4.4 Mode $12 - Request Diagnostic Freeze Frame Data
4.4.1 Functional Description
4.4.2 Message Data Bytes
4.5 Mode $13 - Request Diagnostic Trouble Code Information
4.5.1 Functional Description
4.5.2 Message Data Bytes
4.6 Mode $14 - Clear Diagnostic Information
4.6.1 Functional Description
4.6.2 Message Data Bytes
4.7 Mode $17 - Request Status of Diagnostic Trouble Codes
4.7.1 Functional Description
4.7.2 Message Data Bytes
4.8 Mode $18 - Request Diagnostic Trouble Codes by Status
4.8.1 Functional Description
4.8.2 Message Data Bytes
4.9 Mode $20 - Return to Normal Operation
4.9.1 Functional Description
4.9.2 Message Data Bytes
4.10 Modes $21 to $23 - Request Diagnostic Data
4.10.1 Functional Description
4.10.2 Mode $21 Message Data Bytes
4.10.3 Mode $22 Message Data Bytes
4.10.4 Mode $23 Message Data Bytes
4.11 Mode $24 - Request Scaling and Offset / PID
4.11.1 Functional Description
4.11.2 Message Data Bytes
4.11.3 Scaling Byte 1
4.11.4 Scaling Byte 2
4.11.5 Scaling Bytes 3 to n
4.12 Mode $25 - Stop Transmitting Requested Data
4.12.1 Functional Description
4.12.2 Message Data Bytes
4.13 Mode $26 - Specify Data Rates
4.13.1 Functional Description
4.13.2 Message Data Bytes
4.14 Mode $27 - Security Access Mode
4.14.1 Functional Description
4.14.2 Message Data Bytes
4.15 Mode $28 - Disable Normal Message Transmission
4.15.1 Functional Description
4.15.2 Message Data Bytes
4.16 Mode $29 - Enable Normal Message Transmission
4.16.1 Functional Description
4.16.2 Message Data Bytes
4.17 Mode $2A - Request Diagnostic Data Packet(s)
4.17.1 Functional Description
4.17.2 Message Data Bytes
4.18 Mode $2B - Dynamically Define Data Packet by Single Byte Offsets
4.18.1 Functional Description
4.18.2 Message Data Bytes
4.18.3 Message Example
4.19 Mode $2C - Dynamically Define Diagnostic Data Packet
4.19.1 Functional Description
4.19.2 Message Data Bytes
4.19.3 Message Example
4.20 Mode $2F - Input/Output Control by PID
4.20.1 Functional Description
4.20.2 Message Data Bytes
4.21 Mode $30 - Input/Output Control by Data Value ID
4.21.1 Functional Description
4.21.2 Message Data Bytes
4.22 Modes $31 to $33 - Perform Diagnostic Routine by Test Number
4.22.1 Functional Description
4.22.2 Message Data Bytes
4.23 Modes $34 to $37 - Data Transfer
4.23.1 Functional Description
4.23.2 Message Data Bytes
4.24 Modes $38 to $3A - Perform Diagnostic Routine at a Specified Address 48
4.24.1 Functional Description
4.24.2 Message Data Bytes
4.25 Mode $3B - Write Data Block
4.25.1 Functional Description
4.25.2 Message Data Bytes
4.26 Mode $3C - Read Data Block
4.26.1 Functional Description
4.26.2 Message Data Bytes
4.27 Mode $3F - Test Device Present (no operation performed)
4.27.1 Functional Description
4.27.2 Message Data Bytes
4.28 Mode $7F - General Response Message
4.28.1 Functional Description
4.28.2 Message Data Bytes
4.28.3 Message Examples
4.28.4 Response Codes
Appendix A - Diagnostic Test Mode Assignments

1. Scope—This SAE Recommended Practice describes the implementation of Enhanced Diagnostic Test Modes, which are intended to supplement the legislated Diagnostic Test Modes defined in SAE J1979. Modes are defined for access to emission related test data beyond what is included in SAE J1979, and for non-emission related data. This document describes the data byte values for diagnostic messages transmitted between diagnostic test equipment, either on-vehicle or off-vehicle, and vehicle electronic control modules. No distinction is made between test modes for emission related and non-emission related diagnostics. These messages can be used with a diagnostic serial data link such as described in SAE J1850 or ISO 9141-2.

For each test mode, this document includes a functional description of the test mode, request and report message data byte content, and an example if useful for clarification.

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 J1850—Class B Data Communication Network Interface

SAE J1930—E/E Systems Diagnostic Terms, Definitions, Abbreviations and Acronyms

SAE J1962—Diagnostic Connector

SAE J1978—OBD II Scan Tool

SAE J1979—E/E Diagnostic Test Modes

SAE J2012—Recommended Format and Messages for Diagnostic Trouble Codes

SAE J2178—Class B Data Communication Network Messages

SAE J2186—E/E Data Link Security

2.1.2 ISO PUBLICATIONS—Available from ANSI, 1 West 42nd Street, New York, NY 10036-8002.

ISO 9141-2—Road vehicles—Diagnostic systems—CARB requirements for interchange of digital information

2.1.3 CALIFORNIA ARB DOCUMENTS

Mail out #93-27—Title 13, California Code of Regulations, Section 1968.1 Malfunction and Diagnostic System May 21, 1993Requirements—1994 and Subsequent Model-Year Passenger Cars, Light-Duty Trucks, and Medium-Duty Vehicles and Engines

2.1.4 FEDERAL EPA DOCUMENTS

40 CFR Part 86—Control of Air Pollution From New Motor Vehicles and New Motor Vehicle Engines; Federal Register Regulations Requiring On-board Diagnostics

2.2 Definitions

2.2.1 DATA BYTES—Bytes between header bytes and error detection byte.

2.2.2 DIAGNOSTIC TEST MODE—See SAE J1930.

2.2.3 OFFSET—A number used to refer to a data value by specifying its relative position in a list of data values.

2.2.4 PID—PARAMETER IDENTIFICATION NUMBER—A unique identifier used to refer to a specific data value within a module.

2.2.5 SEED / KEY—See SAE J2186

2.2.6 DPID—DATA PACKET IDENTIFICATION NUMBER—An identifier used to refer to a set of data values within a module.

2.2.7 BYTE—A group of eight bits of data, bits 0 through bit 7, where bit 7 is the most significant bit and bit 0 is the least significant bit.

2.2.8 $—Prefix defining a hexadecimal number

2.2.9 NIBBLE—Four bits of data. A byte may be split into two nibbles.

2.2.10 EPA—ENVIRONMENTAL PROTECTION AGENCY (FEDERAL AGENCY)

2.2.11 CARB—CALIFORNIA AIR RESOURCES BOARD (STATE AGENCY)

2.2.12 OBD II—Second generation of On-Board Diagnostic regulations required by the California Air Resources Board.

3. Technical Requirements

3.1 Test Mode Values—Figure 1 indicates the assignment of test mode values, and indicates the type of message and where they are defined, either in SAE J1979, this document, or by the manufacturer.

Test mode values $00 - $0F and $40 - $4F are reserved to be defined in SAE J1979, which currently only includes functionally addressed messages. Usage of shaded test mode values will be defined in this document. Appendix A indicates the test mode values currently defined by both SAE J1979 and SAE J2190.

There is a one-to-one correspondence between request messages and response messages, with bit 6 of the test mode value indicating the message type.

Test Mode Value	Message Type (bit 6)	Where defined
00 - 0F	Request (bit 6 = 0)	SAE J1979
		SAE J2190
40 - 4F	Response to Modes $00-$3F (bit 6 = 1)	SAE J1979
		SAE J2190
10 - 1F	Request (bit 6 = 0)	Reserved for future expansion as needed
20 - 2F		Defined by vehicle manufacturer
30 - 3F		
50 - 5F	Response to Modes $50-$8F (bit 6 = 1)	Reserved for future expansion as needed
60 - 6F		Defined by vehicle manufacturer
70 - 7F		

FIGURE 1—TEST MODE VALUES

3.2 Physical Addressing—Physical addressing is used for all diagnostic test mode messages defined in this document. Typically when using SAE J1850, this type of addressing requires that the target address of the device for which the message is intended be included in the header of the message. In ISO 9141, the addressing is typically done during initialization. Only that device being addressed will respond to the request. Each device will need to be assigned a unique address to be used for communication purposes.

3.3 Miscellaneous Requirements

3.3.1 MESSAGE RESPONSE TIME—The vehicle controllers should respond to a diagnostic request within 100 ms of a request. If there is no response within this time period, the tool can assume no response will be received.

3.3.2 AUTOMATIC RETURN TO NORMAL OPERATION—During a diagnostic procedure, the on-board controllers will often be put into an abnormal mode of operation to aid in diagnostics. Examples are to report diagnostic data periodically, to disable normal message transmission, or substitute an input or output parameter. In practice, the test procedure should return all on-board controllers to a normal mode of operation at the end of the procedure.

If a test device is disconnected from the vehicle before the on-board controllers have returned to normal operation, the controllers should automatically detect that the tool is disconnected and return to a normal mode of operation. This should be accomplished by the on-board controller looking for a diagnostic message from the test device, which should be apparent from the message header. If a diagnostic message is not received for a 5 s period of time, the on-board controller should automatically return to normal operation.

Some diagnostic procedures may require more than 5 s without a required diagnostic message. For these cases, this document specifies a "test tool present" message to be transmitted by the test device at least once every 5 s if there is no other message. On-board controllers should consider this as a diagnostic message and continue in the current mode of operation.

On-board controllers should also return to normal operation at power up or after a controller reset.

3.3.3 DIAGNOSTIC MESSAGE LENGTH—This document only defines the data bytes to be used in a diagnostic message. The actual number of data bytes in a message, referred to as "n" in the message data byte descriptions in this document, depends on the requirements of the test mode and the maximum number of bytes available in a diagnostic message. The maximum number of bytes available depends on the maximum allowable message length and the number of bytes used as a message header, error detection byte(s), or for other protocol specific purposes.

For example, the SAE J1850 data link effectively limits the total number of bytes in a message to 12. If the message strategy includes a 3 byte header, 1 byte CRC, and 1 byte in-message response, then 7 data bytes are available for SAE J2190 functionality. If the message strategy includes a 3 byte header and 1 byte CRC, then 8 data bytes are available.

If other data links are used as the diagnostic data link, such as ISO 9141, there may be other message length limitations and, therefore, different limits on the number of data bytes available for SAE J2190 functionality.

3.3.4 MESSAGE RESPONSE—All diagnostic request messages, except "Test Device Present (Mode $3F)," should receive a response from the target module. A response is optional for the "Test Device Present" message. There are two types of response messages, specific and general. Specific response messages are uniquely paired with each request message, and repeat enough data bytes of the request message to identify the specific request. The "General Response Message (Mode $7F)" has a single test mode value. The response message to be used for a request depends on the type of the request and whether or not the module can perform the request.

When the request is for data and the module can perform the request (positive response), only the specific form of the response can be used. The response will either be a single message, multiple messages with additional data, or periodic multiple messages with updated data values.

If the request is for action, such as a request for entering a mode of operation or command to perform a function, and the module can perform the request (positive response), either the specific response message or general response message can be used. Those requests for which either response type is a valid response have both response types indicated in this document.

If the request for either data or action cannot be performed by the module (negative response), only the general response message can be used.

Figure 2 summarizes the valid response types for different types of requests.

	Positive response	Negative response
Request for data	Specific response only	General response only
Request for action	Specific or general response allowed	General response only

FIGURE 2---VALID RESPONSE TYPES

With the General Response Message a response code is returned. Response codes can indicate a negative or positive response. Standard response codes are included in the section with the definition of the General Response Message.

4. Test Modes

4.1 Modes $00 through $0F---Physically Addressed SAE J1979 Messages---Modes $00 through $0F are reserved to be defined in SAE J1979. The data byte content of the response to an SAE J1979 request when the device is addressed physically should be identical to the data byte content of the response when the device is addressed functionally. The only device that will respond to this request is the device to which the request is directed.

The response to one of these requests will be a Mode $40 through $4F message.

The same PID list as specified in SAE J1979 will apply when the device is physically addressed using the same test mode value. Although SAE J1979 reserves 256 PID values to be defined in that document, SAE J1979 specifies that PID values $21 to $3F are reserved to be defined in this document. Possible values which may be considered to be included are:

Number of header bytes and format
Use of CRC versus checksum for error detection
Use of in-message response
Maximum number of data bytes allowed (based on header and in-message response)
Use of manufacturer specific pins in the SAE J1962 connector

4.2 Mode $10---Initiate Diagnostic Operation

4.2.1 FUNCTIONAL DESCRIPTION---The purpose of this mode is to inform devices on the serial data link that a diagnostic tool is ready to start diagnostic procedures using the data link. The on-board devices may need to alter their normal operation in order for the diagnostic procedures to be effective. One example is that the system may need to reduce the amount of data being sent on the data link to make more time available for the diagnostic messages. Another possibility is that the system may need to degrade its normal operation in order to be able to process the diagnostic requests. Systems that rely on data from modules being diagnosed may not receive data from those modules as frequently as normal. Use of this mode could inform the receiving modules that diagnostic procedures are in progress and they should not set diagnostic trouble codes based on not receiving data at the normal frequency.

An optional "level of diagnostics" byte may be used to indicate how much the normal operation must be altered in order to accommodate the extra diagnostic procedures. These levels and their corresponding amount of change must be predefined in the module by the module manufacturer. The level of diagnostics can be changed by sending a subsequent Mode $10 command.

4.2.2 MESSAGE DATA BYTES---(See Figure 3.)

	Data Bytes (Hex)			
	#1	#2	#3 to #n-1	#n
Request from Tool to Vehicle				
Request diagnostic operation	10	Level (opt.)		
Positive Response from Vehicle to Tool (either of the following is a valid response)				
Confirm diagnostic operation	50	Level (opt.)		
General response	7F	Optional data bytes may be included (see Mode $7F description)		Resp. Code = 00

FIGURE 3---MESSAGE DATA BYTES FOR MODE $10

4.3 Mode $11---Request Module Reset

4.3.1 FUNCTIONAL DESCRIPTION---This mode requests the module to effectively perform a module power on reset. The response message may be sent either before or after the module is reset. The response message may also be sent by modules whenever they perform a power on reset, whether requested by this test mode or not.

An optional data byte may be included in the request to indicate different levels of reset. Examples are:

First time ever connected to vehicle
First time after battery disconnect
After a full normal power down / power up cycle
After minor power supply interruption

4.3.2 MESSAGE DATA BYTES---(See Figure 4.)

	Data Bytes (Hex)			
	#1	#2	#3 to #n-1	#n
Request from Tool to Vehicle				
Request module reset	11	Level (opt.)		
Positive Response from Vehicle to Tool (either of the following is a valid response)				
Confirm module reset	51	Level (opt.)		
General response	7F	Optional data bytes may be included (see Mode $7F description)		Resp. Code = 00

FIGURE 4---MESSAGE DATA BYTES FOR MODE $11

4.4 Mode $12---Request Diagnostic Freeze Frame Data

4.4.1 FUNCTIONAL DESCRIPTION---The purpose of this mode is to allow access to data values which were stored during freeze frame conditions specified by the vehicle manufacturer. Data content, data format, and method of retrieval are specified by the vehicle manufacturer. Typical uses for this mode are to report data stored upon detection of a system malfunction. Multiple frames of data may be stored before and/or after the malfunction is detected. The request for information includes a frame number followed by an optional indication of the data requested.

If the optional data byte is not used, or is $00, then all data for the requested freeze frame will be reported. If the optional byte is used, then the vehicle manufacturer will define the different methods used to specify which data is requested.

The on-board module will respond to this message by transmitting the requested data.

4.4.2 MESSAGE DATA BYTES---(See Figure 5.)

	Data Bytes (Hex)				
	#1	#2	#3	#4	#5 to #n
Request from Tool to Vehicle					
Request diagnostic freeze frame data	12	Frame No.	Method to request data (optional) examples are: Request all data (not included or 00) Request by offset (1 byte) Request by PID (2 bytes) Request by memory address (3 bytes) Request by Data Packet ID Request starting address for data DTC which caused data to be stored Other manufacturer specific method		
Positive Response from Vehicle to Tool					
Report diagnostic freeze frame data	52	Frame No.	Data byte	Data byte	Additional optional data bytes that are in response to this request may be added to fill the message up to the maximum number of available data bytes

FIGURE 5---MESSAGE DATA BYTES FOR MODE $12

4.5 Mode $13---Request Diagnostic Trouble Code Information

4.5.1 FUNCTIONAL DESCRIPTION---The purpose of this mode is to enable a diagnostic test tool to obtain stored emission and non-emission related diagnostic trouble code (DTC) information.

This mode includes the option to request DTC information by function, where function is either powertrain, body, chassis, or undefined. These are the functions used in SAE J2012 to group trouble codes. The first two bits of the first nibble for requests by function are encoded using the same convention as when codes are reported:

00 - powertrain

OMEGA EXHIBIT 2037

01 - chassis
10 - body
11 - undefined

For requests by function using this test mode, the second two bits of the first nibble are 00, and the second nibble is all zeroes. This translates to the following function groups for DTC requests:

$00 - powertrain codes
$40 - chassis codes
$80 - body codes
$C0 - undefined

In addition, this document defines $FF as the function group to request DTC information for all functions.

This test mode can be used to either request diagnostic trouble codes, or request the number of diagnostic trouble codes. There are two ways this mode can request DTCs.

All codes can be requested by including only the test mode value in the request.

Codes can be requested by function group (Powertrain, Chassis, Body, Undefined, or All) by sending the function group followed by $00 as data bytes 2 and 3 ($00 00, $40 00, $80 00, $C0 00, or $FF 00). Requesting codes for all function groups by including $FF 00 yields the same response as not including function group in the request, but may be desired by a manufacturer for consistency with other messages.

There are also two ways this mode can request the number of DTCs.

Number of codes can be requested by including the function group as data byte 2, and not including data byte 3 ($FF as data byte 2 must be supported as a minimum to request the total number of DTC).

Number of codes can be requested by function group (Powertrain, Chassis, Body, Undefined, or All) by sending the function group followed by $FF as data bytes 2 and 3 ($00 FF, $40 FF, $80 FF, $C0 FF, or $FF FF). Requesting number of codes for all function groups by including $FF FF yields the same response as including only $FF as data byte 2 in the request, but may be desired by a manufacturer for consistency with other messages.

The response to a Mode $13 request for DTC will be one or more Mode $53 messages. If no codes are stored in the module, then the module will respond with one of the following:

Mode $53 with no additional data bytes
Mode $53 padded with $00 00 to fill response

Diagnostic trouble codes are transmitted as two bytes. The first two bits (high order) of the first byte for each code will be zeroes to indicate a powertrain code (refer to SAE J2012 - "Recommended Format and Messages for Diagnostic Trouble Codes" for additional interpretation of this structure). The second two bits will indicate the first digit of the diagnostic code (0 through 3). The second nibble of the first byte and the entire second byte are the next three digits of the actual code reported as Binary Coded Decimal (BCD). A powertrain trouble code transmitted as $0143 should be interpreted as P0143, as shown in Figure 6.

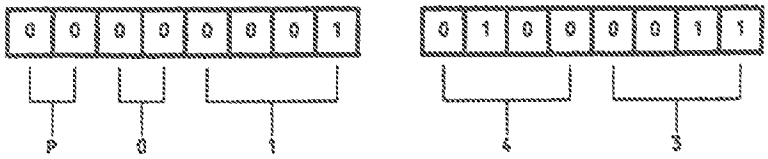


FIGURE 6—DIAGNOSTIC TROUBLE CODE EXAMPLE

4.5.2 MESSAGE DATA BYTES—(See Figure 7.)

	Data Bytes (Hex)			
	#1	#2	#3	#4 to #n
Request from Tool to Vehicle (either of the following messages can be used to request DTC)				
Request all DTC	13			
Request DTC by function group where group is: 00 - powertrain 40 - chassis 80 - body C0 - undefined FF - all	13	Group	00	
Request from Tool to Vehicle (either of the following messages can be used to request number of DTC)				
Request number of DTC by function where group is: 00 - powertrain 40 - chassis 80 - body C0 - undefined FF - all	13	Group		
FF in byte 3 is an optional byte used to maintain a fixed length request	13	Group	FF	
Positive Response from Vehicle to Tool (Multiple messages may be required to report the DTCs)				
Report stored DTC - response to request for DTC	53	Diagnostic trouble code or 00 00 (optional)		Additional optional diagnostic trouble codes may be added to fill the message up to the maximum number of available data bytes.
Report # of stored DTC - response to request for number of DTC	53	Number of codes		

NOTE—Refer to SAE J2012 for encoding method for trouble codes.

FIGURE 7—MESSAGE DATA BYTES FOR MODE $13

4.6 Mode $14—Clear Diagnostic Information

4.6.1 FUNCTIONAL DESCRIPTION—The purpose of this mode is to provide a means for the external test device to command on-board modules to clear all diagnostic information. This information includes primarily diagnostic trouble codes, but can also include freeze frame data or other on-board test results that may be stored as a result of the trouble code being set. This extra information is device dependent.

There are three ways this mode can be used. If only the test mode value is included in the request, then all diagnostic information stored in the module is to be cleared.

Diagnostic information can optionally be cleared by function (Powertrain, Chassis, or Body) by sending P0000, C0000, or B0000 as data bytes 2 and 3. These must be encoded using the same convention as when codes are reported (see description for Mode $13). The first two bits of the first nibble are:

00 - powertrain
01 - chassis
10 - body
11 - undefined

This translates to the following values for data bytes #2 and #3:

$00 00 - powertrain codes
$40 00 - chassis codes
$80 00 - body codes
$C0 00 - undefined

Diagnostic information can also optionally be cleared for a single trouble code by including the trouble code to clear as optional bytes in the request. The information stored with an individual trouble code would need to be clearly identified within the module and cleared at the same time.

Caution when clearing by single trouble code: This capability should not be provided and used unless consideration is given to the possible consequences of this option. If a single fault caused multiple trouble codes to be set, and a service technician found a defective component, repaired it, and cleared a single trouble code associated with that fault, then the device would still contain trouble codes that were set based on that fault. The next technician to check codes would read those codes, and if he did not know the vehicle history, he may try to repair the vehicle based only on the remaining trouble codes, which could waste time and result in replacement of good components.

Allowing use of this feature to clear emission related trouble codes should be considered very carefully to guard against improper diagnosis. Difficult interpretation can result if the system allowed clearing a single emission related trouble code. CARB required information could report that trouble codes are stored, but they would not be reported when an SAE J1979 Mode $04 message is sent to request those codes. Freeze frame data could be stored for a given trouble code, but that code would not be reported as stored.

4.6.2 MESSAGE DATA BYTES—(See Figure 8.)

	Data Bytes (Hex)				
	#1	#2	#3	#4 to #n-1	#n
Request from Tool to Vehicle					
Clear stored diagnostic information	14	Data bytes 2 and 3 are optional # not used - clear all information # 00 01 - clear all powertrain information # 40 00 - clear all chassis information # 80 01 - clear all body information # C0 00 - clear all Cs or DTC information # FF 00 - clear all information Any other value - trouble code to clear			
Positive Response from Vehicle to Tool (either of the following is a valid response)					
Diagnostic information cleared	54	repeat data bytes 2 and 3 of request, if used			
General response	7F	Optional data bytes may be included (see Mode $7F description).			Resp. Code - 00

FIGURE 8—MESSAGE DATA BYTES FOR MODE $14

4.7 Mode $17—Request Status of Diagnostic Trouble Codes

4.7.1 FUNCTIONAL DESCRIPTION—The purpose of this mode is to provide a means to determine the status of diagnostic trouble codes.

This mode is nearly identical in operation to Mode $13, except that only a single DTC, followed by the status of that DTC, is reported in a single response. This mode also allows a request for the status of a single DTC. The discussion of function groups and the method of reporting DTCs is identical to the description in Mode $13.

This test mode can be used to either request status of diagnostic trouble codes, or request the number of diagnostic trouble codes with a status bit set. There are three ways this mode can request DTCs.

All codes can be requested by only including the test mode value in the request.

Codes can be requested by function group (Powertrain, Chassis, Body, Undefined, or All) by sending the function group followed by $00 as data bytes 2 and 3 ($00 00, $40 00, $80 00, $C0 00, or $FF 00). Requesting codes for all function groups by including $FF 00 yields the same response as not including function group in the request, but may be desired by a manufacturer for consistency with other messages.

Status of a single trouble code can be requested by including the trouble code as data bytes 2 and 3 in the request.

There are two ways this mode can request the number of DTCs with a status bit set.

Number of codes can be requested by including the function group as data byte 2, and not including data byte 3 ($FF as data byte 2 must be supported as a minimum to request the total number of DTC).

Number of codes can be requested by function group (Powertrain, Chassis, Body, Undefined, or All) by sending the function group followed by $FF as data bytes 2 and 3 ($00 FF, $40 FF, $80 FF, $C0 FF, or $FF FF). Requesting number of codes for all function groups by including $FF FF yields the same response as including only $FF as data byte 2 in the request, but may be desired by a manufacturer for consistency with other messages.

Multiple Mode $57 response messages may be reported due to a single Mode $17 request message, depending on the type of request and the number of diagnostic trouble codes stored in the module. Each response message will report the status of a single DTC. If no codes are stored in the module, then the module will respond with one of the following:

Mode $57 with no additional data bytes

Mode $57 with $00 00 for DTC and $00 for status

4.7.2 MESSAGE DATA BYTES—(See Figure 9.)

	Data Bytes (Hex)			
	#1	#2	#3	#4
Request from Tool to Vehicle (any of the following messages can be used to request DTC)				
Request status of all DTC	17			
Request status of DTC by function group where group: 00 - powertrain 40 - chassis 80 - body C0 - undefined FF - all	17	Group	00	
Request status of specific DTC	17	Diagnostic Trouble Code		
Request from Tool to Vehicle (either of the following messages can be used to request number of DTC)				
Request number of DTC with a status bit set by function where group is: 00 - powertrain 40 - chassis 80 - body C0 - undefined FF - all	17	Group		
FF in byte 3 is an optional byte used to maintain a fixed length request	17	Group	FF	
Positive Response from Vehicle to Tool (Multiple messages may be required to report the DTCs)				
Report status of stored DTC	57	Diagnostic trouble code or 00 00 (optional)		Status of DTC or 00 (optional if DTC not reported) same definition as Data Byte #2 for Mode $18
Report # of stored DTC with any status bit set	57	Number of codes		

FIGURE 9—MESSAGE DATA BYTES FOR MODE $17

4.8 Mode $18—Request Diagnostic Trouble Codes by Status

4.8.1 FUNCTIONAL DESCRIPTION—This mode is used to retrieve diagnostic trouble codes based on the status by which they have been stored. There are various conditions under which codes are generated, for example, under normal customer driving conditions versus "on demand" codes which are generated by tests performed by the service technician. Another difference is that some codes illuminate a warning lamp while other codes do not. Some codes are retained in memory for at least 40 warmup cycles while some codes are retained only for one ignition/power up cycle.

This test mode is similar in operation to Mode $17, except that an additional data byte is inserted as data byte #2 to indicate the specific status bits of interest. Data bytes #3 and #4 in Mode $18 requests have the same meaning as data bytes #2 and #3 in Mode $17 requests.

There are many philosophies among the various manufacturers for storing codes. Bit definitions have been assigned to the more commonly accepted methods. Codes stored under that definition can be requested by setting the appropriate bit(s) to "1" to retrieve the set of desired codes.

Table 1 shows the interpretation of each bit of the status byte. This definition is used for both Modes $17 and $18. Multiple bits can be set to "1". When requesting codes using Mode $18, codes with any of the requested status bits will be reported.

Multiple Mode $58 response messages may be reported to a single request, depending on the number of diagnostic trouble codes stored in the module. Each response message will report up to three DTCs for which at least one of the requested status bits is set. If no codes are stored in the module that meet the requested status, then the module will respond with one of the following:

Mode $58 with Status Requested and no additional data bytes

Mode $58 with $00 00 as data bytes 3 and 4

Mode $58 with $00 00 repeated to fill response

TABLE 1—INTERPRETATION OF EACH BIT OF THE STATUS BYTE

bit	status
7	Warning lamp illuminated for this code
6	Warning lamp pending for this code, not illuminated but malfunction was detected
5	Warning lamp was previously illuminated for this code, malfunction not currently detected, code not yet erased
4	Stored trouble code
3	Manufacturer specific status
2	Manufacturer specific status
1	Current code - present at time of request
0	Maturing/intermittent code - insufficient data to consider as a malfunction

4.8.2 MESSAGE DATA BYTES—(See Figure 10.)

	Data Bytes (Hex)				
	#1	#2	#3	#4	#5 to #n
Request from Tool to Vehicle (either of the following messages can be used to request DTC)					
Request all DTC with status	18	Status			
Request all DTC with status and function group where group is: 00 - powertrain 40 - chassis 80 - body C0 - undefined FF - all	18	Status	Group	00	
Request from Tool to Vehicle (either of the following messages can be used to request number of DTC)					
Request number of DTC with any specific status bits set by function group 00 - powertrain 40 - chassis 80 - body C0 - undefined FF - all	18	Status	Group		
FF in byte 4 is an optional byte used to maintain a fixed length request	18	Status	Group	FF	
Positive Response from Vehicle to Tool					
Report DTC by status - response to request with test mode and status	58	Status req'd	Diagnostic trouble code or 00 00 (optional)	Additional optional diagnostic trouble codes may be added to fill the message up to the maximum number of available data bytes	
Report DTC by status - response to request with test mode, status, and data byte #3	58	Status req'd	number of DTC with req'd status		

FIGURE 10—MESSAGE DATA BYTES FOR MODE $18

4.9 Mode $20—Return to Normal Operation

4.9.1 FUNCTIONAL DESCRIPTION—The on-board device will return to the normal mode of operation when this message is received. All normal algorithms and normal communications will be resumed. All active diagnostic modes will be terminated without sending additional request or response messages. If the module had been unlocked using security access, then the module should also be locked.

4.9.2 MESSAGE DATA BYTES—(See Figure 11.)

	Data Bytes (Hex)		
	#1	#2 to #n-1	#n
Request from Tool to Vehicle			
Request return to normal operation	20		
Positive Response from Vehicle to Tool (either of the following is a valid response)			
Confirm return to normal operation	60		
General response	7F	Optional data bytes may be included (see Mode $7F description)	Resp. Code - 60

FIGURE 11—MESSAGE DATA BYTES FOR MODE $20

4.10 Modes $21 to $23—Request Diagnostic Data

4.10.1 FUNCTIONAL DESCRIPTION—The purpose of these modes is to request data values, such as analog inputs and outputs, digital inputs and outputs, freeze frame data, calculated values, bit mapped fault code data, and system status information. The request for information can be by one of three methods:

Mode $21 - Offset (1 byte)
Mode $22 - Parameter Identification (PID) value (2 bytes)
Mode $23 - Memory Address (3 bytes)

System designers have the flexibility to maintain a table including PID numbers and data values, without having consecutive PID numbers. In this case, the tool can request either by PID number or offset. A request by offset is generally an easier method for the software to retrieve data because it does not need to search for the PID in the table. Mode $24 allows use of the PID number one time to get the offset, with successive requests by offset for better system performance.

Figure 12 is an example of a table that could be included in the system module to utilize all of these modes. The offset is the row number of the table and is not a table entry. The location of the information within this table can be calculated by multiplying the offset times the number of bytes in each row. The location in memory can then be calculated by adding the location within the table to the base location of the table in memory.

Offset	PID1	PID2	ADDR1	ADDR2	ADDR3	SCALING1	SCALING2
00	00	01	00	1B	FE		
01	05	0A	02	2C	12		
02	01	FE	09	8A	1F		
..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..
2E	04	0C	00	05	8A		

FIGURE 12—OFFSET/PID/ADDRESS TABLE EXAMPLE

A Mode $21 request by offset would calculate the location of the offset information in the table, find the address and scaling for that value, and return the appropriate number of bytes of information starting at that address.

A Mode $22 request by PID would search through the table for the requested PID, find the address and scaling for that value, and return the appropriate number of bytes of information starting at that address.

A Mode $23 request by address would ignore this table and report data starting at the address specified in the request.

4.10.2 MODE $21 MESSAGE DATA BYTES—(See Figure 13.)

Page 647 of 1656 OMEGA EXHIBIT 2037

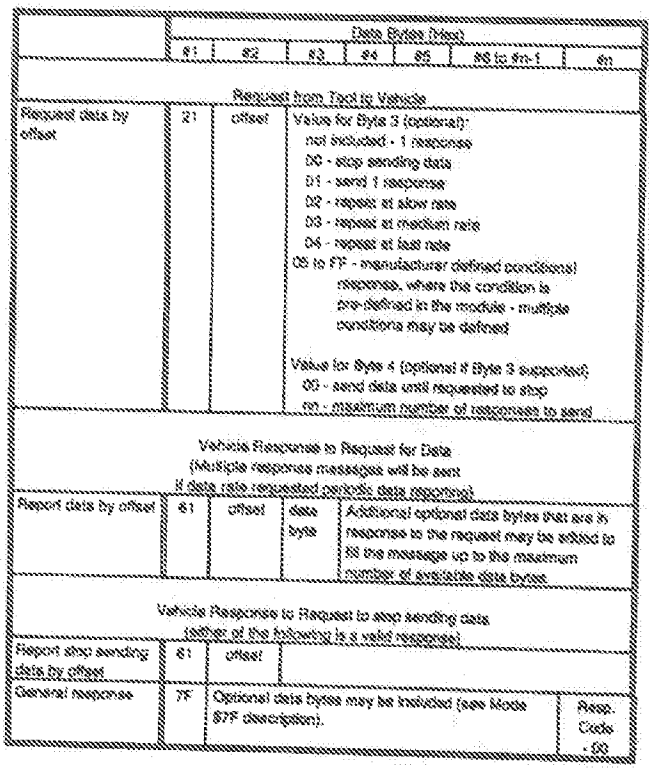


FIGURE 13—MESSAGE DATA BYTES FOR MODE $21

4.10.3 MODE $22 MESSAGE DATA BYTES—(See Figure 14.)

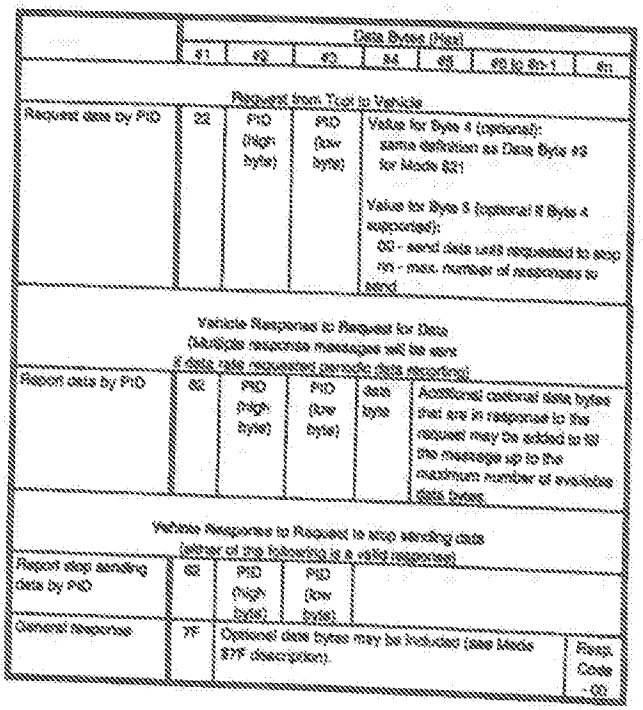


FIGURE 14—MESSAGE DATA BYTES FOR MODE $22

4.10.4 MODE $23 MESSAGE DATA BYTES—(See Figure 15.)

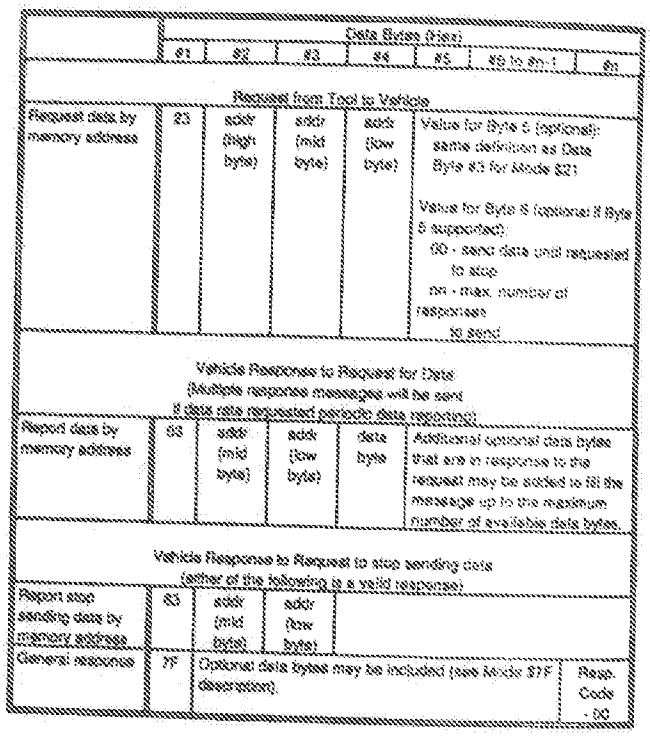


FIGURE 15—MESSAGE DATA BYTES FOR MODE $23

4.11 Mode $24—Request Scaling and Offset / PID

4.11.1 FUNCTIONAL DESCRIPTION—The purpose of Mode $24 is to request either scaling and PID information by specifying offset, or request scaling and offset information by specifying PID. $FF should be included in the request for the data byte value not being specified. If both offset and Parameter ID are specified, and the parameter ID is not correct for the offset specified, unexpected data values can be returned. Operation of this mode is similar to either Mode $21 or $22, depending on which value was specified in the request. The response would include offset, PID, and scaling for the requested entry. Any data byte values not supported by the module would report $FF.

Mode $24 can also be used to determine the PID table by incrementing the offset in repeated Mode $24 requests.

4.11.2 MESSAGE DATA BYTES—(See Figure 16.)

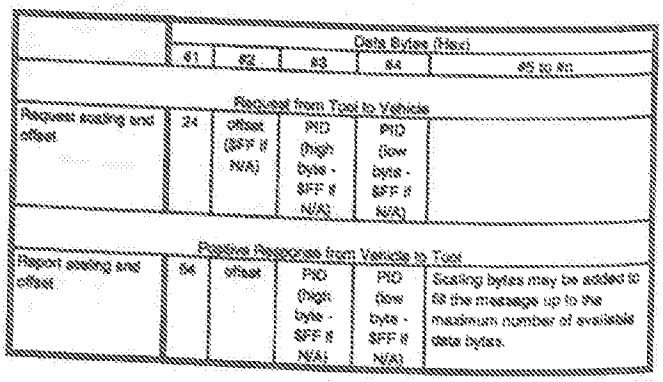


FIGURE 16—MESSAGE DATA BYTES FOR MODE $24

4.11.3 SCALING BYTE 1
High nibble (bits 7 to 4)

data type
0000 - Unsigned numeric (1 to 4 bytes)
0001 - Signed numeric (1 to 4 bytes)
0010 - Bit mapped, reported without mask
0011 - Bit mapped, reported with mask
0100 - BCD (1 to 4 bytes)
0101 - State encoded
0110 - ASCII
0111 - Signed floating point (ANSI/IEEE Std 754-1985)
1000 - Packet
1001 - Formula
1010 thru 1111 - Reserved

Low nibble (bits 3 to 0)
number of bytes of value
0000 - Reserved
0001 - 1 byte
0010 - 2 bytes
0011 - 3 bytes
0100 - 4 bytes
0101 thru 1111 - Reserved - may be greater than 4 for non-numeric data (ASCII or bit-mapped)

The high order nibble of the first byte defines the type of information encoding which is used to represent the parameter. The low order nibble can be read directly to determine the number of bytes used to represent the parameter.

4.11.3.1 Unsigned Numeric---This encoding uses a common binary weighting scheme to represent a value by means of discrete incremental steps. One byte affords 256 steps, two bytes yields 65 536 steps, etc. For example, vehicle speed may be encoded with a single unsigned numeric parameter ranging from 0 to 255 km/h. This unsigned numeric value may be up to 4 bytes in length.

4.11.3.2 Signed Numeric---This encoding uses a two's complement binary weighting scheme to represent a value by means of discrete incremental steps. One byte affords 256 steps; two bytes yields 65,536 steps, etc. A value can be encoded with a single unsigned numeric parameter ranging from -127 to 128. This signed numeric value may be up to 4 bytes in length.

4.11.3.3 Bit Mapped---Bit mapped encoding uses individual bits or small groups of bits to represent status. For every bit which represents status, a corresponding mask bit is required as part of the parameter definition. The mask indicates the validity of the bit for particular applications. A bit mapped parameter may contain 2 bytes; one representing status and one containing the validity mask, or 4 bytes; the first two representing status and the second two containing validity masks. Reference J2178, Part 2 for a discussion of bit mapped data values.

4.11.3.4 BCD---Conventional BCD encoding is used to represent two numeric digits per byte. The upper nibble is used to represent the most significant digit (0 - 9), and the lower nibble the least significant digit (0 - 9). Up to 8 characters (4 bytes) may comprise a single parameter.

4.11.3.5 State Encoded---This encoding uses a common binary weighting scheme to represent up to 256 distinct states. An example is a parameter which represents the status of the ignition switch. Codes "00," "01," "02," and "03" may indicate ignition off, locked, run, and start, respectively. The representation is always limited to 1 byte.

4.11.3.6 ASCII---Conventional ASCII encoding is used to represent up to 128 standard characters (MSB = logic 0). An additional 128 custom characters may be represented with MSB = logic 1. Up to four ASCII characters may comprise a single parameter.

4.11.3.7 Signed Floating Point---Floating point encoding is used for data that needs to be represented in floating point or scientific notation. Standard IEEE formats shall be used.

4.11.3.8 Packet---Packets contain multiple data values, usually related, each with unique scaling. Scaling information is not included for the individual values.

4.11.3.9 Formula---Different formulas are currently being discussed to be included. The formula type and constant values used in those formulas will be specified in scaling bytes, or reported as a different test mode.

4.11.4 SCALING BYTE 2---This byte is only relevant for signed and unsigned numbers and for bit mapped parameters. For other parameter types, this field is "padded" with $00. When used with signed and unsigned numbers, this byte specifies scaling by indicating the binary point location. The binary point may be moved 127 places to the right ($FF) or 128 places to the left ($00). The binary point is initially assumed to be to the right of the LSB without this information.

When this byte is used for bit mapped parameters that are reported without a mask, this byte indicates which bits of the PID are supported for the current application. When bit mapped data is reported with a mask, this byte is not used.

When the data type is "formula," this byte is used to indicate the formula type, where:

$00 - $7F are reserved for SAE to define
$80 - $FF are reserved for the manufacturer to define

4.11.5 SCALING BYTES 3 TO N---Optional bytes to be included if multiple bytes of bit mapped data are reported. This mode is more limiting in the number of masks that can be reported than the modes that allow retrieval of the data.

4.12 Mode $25---Stop Transmitting Requested Data

4.12.1 FUNCTIONAL DESCRIPTION---The purpose of Mode $25 is to stop all data transmission that was started by any test mode that can request repetitive data. If only an individual data request is to be stopped, then that value can be stopped by sending a request message for the mode that requested the data with a "0" for the data rate. In practice, if a message is already in an outgoing message queue ready to be sent, this would probably not remove that message from the queue, but it would prevent additional messages from being added to the queue. Response is either Mode $65 or general response.

4.12.2 MESSAGE DATA BYTES---(See Figure 17.)

		Data Bytes (Hex)		
	#1	#2 to #n-1		#n
Request from Tool to Vehicle				
Request all data stop	25			
Positive Response from Vehicle to Tool (either of the following is a valid response)				
Confirm all data stopped	65			
General response	7F	Optional data bytes may be included (see Mode $7F description)		Resp. Code - 00

FIGURE 17---MESSAGE DATA BYTES FOR MODE $25

4.13 Mode $26---Specify Data Rates

4.13.1 FUNCTIONAL DESCRIPTION---The purpose of Mode $26 is to specify the setting of data rates for data to be transmitted by request messages that can request repetitive data. Those modes include "Data Rate" as a data byte in the request message. Modules will normally have default rates associated with slow, mid, and fast. The slow rate should be about one or two samples per second, the mid rate should be normal handheld scan tool rates of about four to ten samples per second, and the fast rate 20 or more samples per second. Default rates are defined within each module and should be based on the frequency of change typical for the value reported, uses for that data, and the capability of the processor.

4.13.2 MESSAGE DATA BYTES---(See Figure 18.)

		Data Bytes (Hex)					
	#1	#2	#3	#4	#5 to #n-1		#n
Request from Tool to Vehicle							
Request data rate values	26	Slow Rate * - 40 msec per bit	Mid Rate * - 8 msec per bit	Fast Rate * - 1 msec per bit			
Positive Response from Vehicle to Tool (either of the following is a valid response)							
Confirm data rate values set	66						
General response	7F	Optional data bytes may be included (see Mode $7F description).					Resp. Code - 00

* NOTE: A value of $00 should cause the data to be reported as fast as possible. A value of $FF will cause no change in the current data rate.

FIGURE 18---MESSAGE DATA BYTES FOR MODE $26

4.14 Mode $27---Security Access Mode

Page 649 of 1656 OMEGA EXHIBIT 2037

4.14.1 FUNCTIONAL DESCRIPTION—The primary purpose of this mode is to restrict unauthorized intrusion into the on-board controller. Improper programs could potentially damage the electronics or other vehicle components or risk the vehicle's compliance to emission or safety standards. This mode is intended to be used to implement the data link security measures defined in SAE J2186.

The external device will request the controller to "Unlock" itself by sending Request #1. The controller will respond by sending a "Seed" using Response #1. The external device will respond by returning a "Key" number back to the controller using Request #2. The controller would compare this "Key" to one internally stored. If the two numbers agree, then the controller will enable ("Unlock") the external device's access to specific test modes and indicate that with Mode $67, Response #2. If upon two attempts of a Request #2 where the two keys do not compare, then the controller will insert a 10 s time delay before allowing further attempts. This time delay will also be required before responding to a Mode $27 request #1 for each controller power-on.

If a device supports security, but is already unlocked when a Request #1 is received, that device should respond with a Response #1 message with a seed of $00 00. A test device could use this method to determine if a device is locked by checking for a non-zero seed.

The security system will not prevent normal diagnostic or vehicle communications between external devices and the on-board controller. Proper "Unlocking" of the controller is a prerequisite to the external device's ability to perform some of the more critical functions such as reading specific memory locations within the controller, downloading information to specific locations, or downloading routines for execution by the controller. In other words, the only access to the controller permitted while in a "locked" mode is through the product specific software. This permits the product specific software to protect itself from unauthorized intrusion.

Devices that provide security should support reject messages if a secure mode is requested while the device is locked. The reject message to be returned is a general response message Mode $7F, with a response code $33 to indicate the product is secured.

Some devices could support multiple levels of security, either for different functions controlled by the device, or to allow different capabilities to be exercised. These additional levels of security can be accessed by using requests #3 and #4, etc. The second data byte of the request for seed should always be an odd number, and the second data byte of the message to send the key should be the next even number.

4.14.2 MESSAGE DATA BYTES—(See Figure 19.)

	Data Bytes (Hex)					
	#1	#2	#3	#4	#5 to #n-1	#n
Request #1 from Tool to Vehicle (data byte #2 can be an odd number greater than $01 if additional levels of security are supported)						
Request for "Seed"	27	01 (03, etc.)				
Positive Response #1 from Vehicle to Tool						
Return "Seed"	67	01 (03, etc.)	Seed (00 00 if module is not locked)		Optional data bytes may be specified by the vehicle manufacturer	
Request #2 from Tool to Vehicle (data byte #2 can be an even number one greater than data byte #2 of request #1 if additional levels of security are supported)						
Send "Key"	27	02 (04, etc.)	Key			
Positive Response #2 from Vehicle to Tool						
Security access	67	02 (04, etc.)	Optional data bytes may be specified by the vehicle manufacturer			
General response	7F	Optional data bytes may be included (see Mode $7F description).				Resp. Code - 00

FIGURE 19—MESSAGE DATA BYTES FOR MODE $27

4.15 Mode $28—Disable Normal Message Transmission

4.15.1 FUNCTIONAL DESCRIPTION—The purpose of this mode is to inhibit the on-board device from transmitting normal operating data on the link, while still performing other functions normally. The device will continue to operate in whatever diagnostic mode it was operating in prior to the Mode $28 command.

If an unsafe or undesirable vehicle operating condition would result from the lack of normal messages, then this mode could cause all nonessential messages to be inhibited. The optional manufacturer specific "level" data byte could be used to indicate which normal mode messages to disable. Defining which messages to disable is determined by the system designer to ensure safe vehicle operation. When using this test mode, some provision must be made to allow for other devices that rely on information from the silenced device so that they do not set diagnostic trouble codes due to the lack of required information.

One use for this test mode is to reduce message traffic on the data link. This would make more time available for diagnostic messages. Another use for this mode is to allow the test equipment to emulate the remote device for diagnostic purposes. In this scenario, the test device would send a Mode $28 request to the device to be emulated. The test device would then respond to all normal communication request messages directed to that device, most likely with data intended to cause a known response by a system that uses the information in the response. The test device can then observe the actions of these systems.

4.15.2 MESSAGE DATA BYTES—(See Figure 20.)

	Data Bytes (Hex)			
	#1	#2	#3 to #n-1	#n
Request from Tool to Vehicle				
Request disable normal message transmission	28	Level (opt.)		
Positive Response from Vehicle to Tool (either of the following is a valid response)				
Confirm normal message transmission disabled	68	Level (opt.)		
General response	7F	Optional data bytes may be included (see Mode $7F description)		Resp. Code - 00

FIGURE 20—MESSAGE DATA BYTES FOR MODE $28

4.16 Mode $29—Enable Normal Message Transmission

4.16.1 FUNCTIONAL DESCRIPTION—The purpose of this mode is to cause an on-board device to resume normal communications after previously disabling these messages by a Mode $28 command. The device will continue to operate in whatever diagnostic modes were set by previous messages, such as executing on-board routines.

4.16.2 MESSAGE DATA BYTES—(See Figure 21.)

	Data Bytes (Hex)		
	#1	#2 to #n-1	#n
Request from Tool to Vehicle			
Request enable normal message transmission	29		
Positive Response from Vehicle to Tool (either of the following is a valid response)			
Confirm normal message transmission enabled	69		
General response	7F	Optional data bytes may be included (see Mode $7F description)	Resp. Code - 00

FIGURE 21—MESSAGE DATA BYTES FOR MODE $29

4.17 Mode $2A—Request Diagnostic Data Packet(s)

4.17.1 FUNCTIONAL DESCRIPTION—The purpose of this mode is to request diagnostic data packets that contain data values, such as analog inputs and outputs, digital inputs and outputs, freeze frame data, calculated values, bit mapped fault code data, and system status information. This Mode differs from Modes $21 through $23 in that multiple data packets can be requested, each containing multiple data values. These data packets can either be predefined in the on-board control module or dynamically defined using Mode $2B or $2C.

The on-board module will respond to this message by transmitting multiple response messages specific to that device. The data packet ID Bytes in the request allow multiple Mode $2A data packets to be requested. Data packets should be defined which include data that is commonly used together, or changes together.

Uses for these different data packets include data such as wheel speeds for an ABS system. Data can be returned quickly with a minimal length request and response. Another use for these different data packets is to return values that do not change, such as VIN and option content. These values need to be known one time only during testing. Other data bytes may contain present values of analog and discrete device I/O, device software flags and status words, and failure codes.

4.17.2 MESSAGE DATA BYTES---(See Figure 22.)

	Data Bytes (Hex)				
	#1	#2	#3	#4 to #n-1	#n
Request from Tool to Vehicle					
Request diagnostic data packets	2A	Data rate *	DPID #	Additional optional data packet IDs may be requested to fill the message up to the maximum number of available data bytes.	
Positive Response from Vehicle to Tool (Multiple response messages will be sent if multiple DPIDs requested, or if data rate requested periodic data reporting)					
Report of diagnostic data packet - repeated for each requested data packet	2A	DPID #	Data Byte	Additional optional data bytes that are in response to the request may be added to fill the message up to the maximum number of available data bytes.	
Vehicle Response to Request to stop sending data (either multiple $FF messages or a single $7F message is a valid response)					
Report stop sending diagnostic data packets	5A	DPIDs of DPID req.	(any additional DPID #s in this message could appear to be data)		
Report report stop sending diagnostic data packets for each DPID # requested	5A	DPID # of DPID req.			
General response	7F	Optional data bytes may be included (see Mode $7F description)			Resp. code - 00

* same data rate definition as Data Byte #3 for Mode $21

FIGURE 22---MESSAGE DATA BYTES FOR MODE $2A

4.18 Mode $2B---Dynamically Define Data Packet by Single Byte Offsets

4.18.1 FUNCTIONAL DESCRIPTION---This test mode can be used to dynamically define data packets that can subsequently be requested using a Mode $2A request. This mode is a special case alternative to using multiple Mode $2C messages, because a single request message can be used to completely define the contents of a data packet. All other methods to specify the data values to be included in data packets using Mode $2C would also require multiple messages, therefore, special modes to build data packets by PID or memory address are not included.

If the parameter for any offset value is longer than 1 byte, then offset data bytes in the request should be filled with $FF for each additional byte in the data value requested (see message example). This forces the data value byte locations in the response message to mirror the offset value byte locations in the request message.

4.18.2 MESSAGE DATA BYTES---(See Figure 23.)

4.18.3 MESSAGE EXAMPLE---Figure 24 is an example of messages required to define a data packet by offset and then request that data packet. The data packet can be defined with a single message and requested with another message.

	Data Bytes (Hex)				
	#1	#2	#3	#4 to #n-1	#n
Request from Tool to Vehicle					
Define diagnostic data packet	2B	DPID #	Offset	Additional optional data offset values may be added to fill the message up to the maximum number of available data bytes.	
Positive Response from Vehicle to Tool (either of the following is a valid response)					
Confirm diagnostic data packet defined	6B	DPID #			
General response	7F	Optional data bytes may be included (see Mode $7F description)			Resp. Code - 00

FIGURE 23---MESSAGE DATA BYTES FOR MODE $2B

	Data Bytes (Hex)							
	#1	#2	#3	#4	#5	#6	#7	#8
Define Diagnostic Data Packet #22 consisting of: Value at offset $30 (1 byte value) Value at offset $12 (2 byte value) Value at offset $26 (2 byte value) Value at offset $05 (1 byte value)								
Define diagnostic data packet #22	2B	22	30	12	FF	26	FF	05
Positive Response from Vehicle to Tool (either of the following is a valid response)								
Confirm data packet defined #22	6B	22						
General response	7F	2B	22	Resp. Code - 00				
Request from Tool to Vehicle								
Request data packet #22	2A	Data rate	22					
Positive Response from Vehicle to Tool								
Report data packet #22	6A	22	1 byte value from offset $30	2 byte value from offset $12	2 byte value from offset $26	1 byte value from offset $05		

FIGURE 24---DATA PACKET EXAMPLE

4.19 Mode $2C---Dynamically Define Diagnostic Data Packet

4.19.1 FUNCTIONAL DESCRIPTION---This test mode can be used to dynamically define data packets that can subsequently be requested using a Mode $2A request. This single test mode is an alternative to multiple modes to define data packets by offset, PID, and memory address.

This mode allows data packets to be defined in different ways, and also allows a single data packet to include data specified in different ways. Multiple messages must be sent to define a single data packet. Each message constructs a portion of the data packet, and includes an indication of how the data is being requested, the starting byte of the data packet, and the number of bytes to be specified for the data packet.

Data packets can be shortened by sending a data packet definition with the starting byte indicating the first data byte not to be included, and 0 as the length. This should be interpreted as 0 bytes at the starting location, which means that data byte is not in the response message.

Data packet definitions can be cleared by sending a message with 1 as the starting data byte and 0 as the number of bytes. Requesting this data packet would result in a response which would include the mode value, data packet ID, and no data.

Data packet definitions can be removed by sending a message with 0 as the starting data byte and 0 as the number of bytes. This would free memory space, if needed.

An optional feature of this mode is to request the present definition for the data packet. This is accomplished by sending a Mode $2B with the data packet ID as the only additional data byte. The result is multiple $6B responses, each including data bytes that resemble the $2B messages that created the data packet.

4.19.2 MESSAGE DATA BYTES---(See Figure 25.)

	Data Bytes (Hex)				
	#1	#2	#3	#4 to #n-1	#n
Request from Tool to Vehicle					
Define diagnostic data packet	2C	DPID #	Data byte #3 bits 7,6 if 00 - define by offset (1 byte) if 01 - define by PID (2 bytes) if 10 - define by memory address (3 bytes) if 11 - manufacturer defined bits 5,4,3 starting byte for data, where 001 is the first byte after the DPID # bits 2,1,0 number of data bytes for this parameter Data bytes starting at byte #4 contain either the offset, PID, memory address, or manufacturer defined value for the data to be included in the packet		
Positive Response from Vehicle to Tool (either of the following is a valid response)					
Confirm diagnostic data packet defined	6C	DPID #	Request data byte #3		
General response	7F	Optional data bytes may be included (see Mode $7F description).			Resp. Code - 00

FIGURE 25---MESSAGE DATA BYTES FOR MODE $2C

4.19.3 MESSAGE EXAMPLE---Figure 26 shows the messages required to define a data packet and then request that data packet. Data packet #26 is to be defined as:

Value for PID $01 04 (1 byte data value)
Value at offset $32 (2 byte data value)
2 bytes of data at memory address $24 81 70

This definition requires three sets of request / report messages, and the data packet request requires one set of messages.

4.20 Mode $2F---Input/Output Control by PID

4.20.1 FUNCTIONAL DESCRIPTION---This capability allows the tester to verify proper operation of external input and output components and circuitry by isolation techniques. Real world sensor inputs can be temporarily bypassed, and direct control of output devices can be achieved. Since substitution may cause the control module to operate in a manner which is unsuitable or unsafe for "on-the-road" operation, precautions must be taken to ensure safe operation. The substituted value is used only for the duration of the diagnostic procedure, and when the module is returned to normal operation, or control of the data value is returned to the vehicle, then the substituted value reverts back to the normal value determined by the control system.

Parameter IDs (PIDs) are assigned by the manufacturer for those input, output, and intermediate (calculated) values that are allowed to be substituted. The PID assignments can be the same PID values that are used with a Mode $22 request for data by PID.

4.20.2 MESSAGE DATA BYTES---(See Figure 27.)

	Data Bytes (Hex)						
	#1	#2	#3	#4	#5	#6	#7
Request from Tool to Vehicle							
PID $01 04 is 1 byte value to be included at data byte 3 (1 byte after DPID #)	2C	28	49 01 001 001 1 1	01	04		
Positive Response from Vehicle to Tool (either of the following is a valid response)							
PID $01 04 at data byte 3	6C	28	49				
General response	7F	2C	28	49	Resp. Code - 00		
Request from Tool to Vehicle							
Offset $32 is 2 byte value to be included at data byte 4 (2 bytes after DPID #)	2C	28	12 000 010 010 2 2	32			
Positive Response from Vehicle to Tool (either of the following is a valid response)							
Offset $32 starting at data byte 4	6C	28	12				
General response	7F	2C	28	12	Resp. Code 00		
Request from Tool to Vehicle							
2 bytes starting at address $24 81 70 to be included at data bytes 6 and 7	2C	28	A2 10 100 010 4 2	24	81	70	
Positive Response from Vehicle to Tool (either of the following is a valid response)							
Addresses $24 81 70 and $24 81 71 at data bytes 6 and 7	6C	28	A2				
General response	7F	2C	28	A2	Resp. Code - 00		
After the data packet is defined, the tool can request the data packet from the vehicle							
Request data packet #26	2A	28					
Positive Response from Vehicle to Tool							
Report data packet #26	6A	28	1 byte value for PID $01 04	2 byte value from offset $32	2 bytes at memory address $24 81 70		

FIGURE 26---DATA PACKET DEFINITION EXAMPLE

4.21 Mode $30---Input/Output Control by Data Value ID

4.21.1 FUNCTIONAL DESCRIPTION---This mode is identical in purpose and function to Mode $2F, except that the parameter to be controlled is specified by a 1 byte Data Value ID instead of a 2 byte PID.

Data value IDs are assigned by the manufacturer for those input, output, and intermediate (calculated) values that are allowed to be substituted.

4.21.2 MESSAGE DATA BYTES---(See Figure 28.)

	Data Bytes (Hex)					
	#1	#2	#3	#4	#5 to #n-1	#n
Request from Tool to Vehicle						
Request Input/Output control by PID	2F	PID (high byte)	PID (low byte)	Data Byte #4 (optional) If not specified - control of identified data value is disabled If specified - value is substituted for identified data value in the module Data Bytes after #4 may be used if needed to specify substitute value		
Positive Response from Vehicle to Tool (either of the following is a valid response)						
Confirm Input/Output control by PID	6F	PID (high byte)	PID (low byte)	Req. data byte 4 (opt)		
General response	7F	Operation data bytes may be included (see Mode $7F description).				Resp. Code - 00

FIGURE 27—MESSAGE DATA BYTES FOR MODE $2F

	Data Bytes (Hex)				
	#1	#2	#3	#4 to #n-1	#n
Request from Tool to Vehicle					
Request Input/Output control by data value ID	30	Data value ID	Data Byte #3 (optional) If not specified - control of identified data value is disabled If specified - value is substituted for identified data value in the module Data Bytes after #3 may be used if needed to specify substitute value		
Positive Response from Vehicle to Tool (either of the following is a valid response)					
Confirm Input/Output control by data value ID	70	Data value ID	Req. data byte 3 (opt)		
General response	7F	Optional data bytes may be included (see Mode $7F description).			Resp. Code - 00

FIGURE 28—MESSAGE DATA BYTES FOR MODE $30

4.22 Modes $31 to $33—Perform Diagnostic Routine by Test Number

4.22.1 FUNCTIONAL DESCRIPTION—The purpose of these modes is to execute diagnostic tests and obtain test results. The diagnostic routines are manufacturer defined and executed in the control module by referencing the test number. Each module may support up to 255 distinct diagnostic routines. Definition of the routines is defined by the module manufacturer.

Reported results may consist of any set of return information, such as measured test values or fault codes.

Three sets of messages are used to perform tests resident in an on-board control module. These messages perform three functions:

Mode $31 - Enter/start Diagnostic Routine by Test Number
Mode $32 - Exit/stop Diagnostic Routine by Test Number
Mode $33 - Request Diagnostic Routine Results by Test Number

The tests are known by the module and identified by a test number. They are usually permanently stored in the module, but may have been downloaded by Modes $34 and $36.

These test numbers could either be tests that run instead of normal operating code, or could be routines that are enabled in this mode and execute with the normal operating code. In the first case, normal system operation for the controller being tested is not possible. In the second case, multiple diagnostic routines can be enabled that run while all other parts of the system are functioning normally.

Any combination of the messages can be used, depending on the implementation in the module. Some examples are:

Tester sends a Mode $31 message to start a test. The module reports that the test has started with a Mode $71 and runs the test until a Mode $32 is sent to stop the test. The module exits the test and informs the tester with a Mode $72 that the test has stopped. The tester then requests test results with a Mode $33, and the module reports the results with a Mode $73 message.

Tester sends a Mode $31 message to start a test. The Module confirms the test has started, exits when the test is done and reports results using Mode $73.

Tester sends a Mode $31 message to start a test. The Module starts the test and periodically reports results using Mode $73 until a Mode $32 is sent to stop the test.

The on-board controller starts a test automatically, stops the test automatically and reports results using a Mode $73 message automatically. This requires no request messages from the tester.

These examples demonstrate both maximum and minimum use of the available message. Test equipment needs to know what tests are available, which messages are required, and how to interpret the results.

The general purpose response, Mode $7F, may also be used instead of a Mode $71 or Mode $72 message to acknowledge entry or exit from a diagnostic routine.

4.22.2 MESSAGE DATA BYTES—(See Figure 29.)

	Data Bytes (Hex)				
	#1	#2	#3	#4 to #n-1	#n
Request from Tool to Vehicle					
Request entry by test number	31	Test #	Additional optional data bytes may be added to the request to fill the message up to the maximum number of available data bytes.		
Positive Response from Vehicle to Tool (either of the following is a valid response)					
Report entry by test number	71	Test #	Additional optional data bytes that are in response to the request may be added to fill the message up to the maximum number of available data bytes.		
General response	7F	Optional data bytes may be included (see Mode $7F description).			Resp. code - 00
Request from Tool to Vehicle					
Request exit by test number	32	Test #	Additional optional data bytes may be added to the request to fill the message up to the maximum number of available data bytes.		
Positive Response from Vehicle to Tool (either of the following is a valid response)					
Report exit by test number	72	Test #	Additional optional data bytes that are in response to the request may be added to fill the message up to the maximum number of available data bytes.		
General response	7F	Optional data bytes may be included (see Mode $7F description).			Resp. code - 00
Request from Tool to Vehicle					
Request results by test number	33	Test #	Additional optional data bytes may be added to the request to fill the message up to the maximum number of available data bytes.		
Positive Response from Vehicle to Tool					
Report results by test number	73	Test #	Additional optional data bytes that are in response to the request may be added to fill the message up to the maximum number of available data bytes.		

Note: Mode $33 reports the results of a test that was run on request from a tool. This differs from Mode $06, which reports the results of the latest on-board monitoring test that was run to meet OBD regulations.

FIGURE 29—MESSAGE DATA BYTES FOR MODES $31 THROUGH $33

4.23 Modes $34 to $37—Data Transfer

4.23.1 FUNCTIONAL DESCRIPTION—These modes allow the transfer of data either from a tester to an on-board module or from an on-board module to a tester. Modes defined are:

Mode $34 - Request Download - tool to module
Mode $35 - Request Upload - module to tool

Page 653 of 1656 OMEGA EXHIBIT 2037

Mode $36 - Data Transfer
Mode $37 - Request Data Transfer Exit

Download is defined as data transfer from the tool to the controller in the vehicle. Upload is defined as data transfer from the controller in the vehicle to the tool.

4.23.2 MESSAGE DATA BYTES—(See Figure 30.)

	Data Bytes (Hex)		
	#1	#2 to #n-1	#n
Request from Tool to Vehicle			
Request download	34	Messages used to request download are defined by the vehicle/module manufacturer. This Mode value is reserved for a download request message.	
Positive Response from Vehicle to Tool (either of the following is a valid response)			
Report download status	74	Messages used to request download are defined by the vehicle/module manufacturer. This Mode value is reserved for the response to a Mode $34.	
General response	7F	Optional data bytes may be included (see Mode $7F description).	Resp. code - 00
Request from Tool to Vehicle			
Request upload	35	Messages used to request upload are defined by the vehicle/module manufacturer. This Mode value is reserved for an upload request message.	
Positive Response from Vehicle to Tool (either of the following is a valid response)			
Report upload status	75	Messages used to request download are defined by the vehicle/module manufacturer. This Mode value is reserved for the response to a Mode $35.	
General response	7F	Optional data bytes may be included (see Mode $7F description).	Resp. code - 00
Transfer Data			
Data transfer	36	Messages used to perform the data transfer are defined by the vehicle/module manufacturer. This Mode value is reserved for the data transfer request message.	
Data transfer	76	Messages used to perform the data transfer are defined by the vehicle/module manufacturer. This Mode value is reserved for the response to a Mode $36.	
Request from Tool to Vehicle			
Request exit	37	Messages used to exit data transfer are defined by the vehicle/module manufacturer. This Mode value is reserved for the exit data transfer request message.	
Positive Response from Vehicle to Tool (either of the following is a valid response)			
Report exit	77	Messages used to exit data transfer are defined by the vehicle/module manufacturer. This Mode value is reserved for the response to a Mode $37.	
General response	7F	Optional data bytes may be included (see Mode $7F description).	Resp. code - 00

FIGURE 30—MESSAGE DATA BYTES FOR MODES $34 THROUGH $37

4.24 Modes $38 to $3A—Perform Diagnostic Routine at a Specified Address

4.24.1 FUNCTIONAL DESCRIPTION—These test modes are used to execute code resident in the on-board controller at the specified address. This executable code may be permanently stored in the controller or may have been downloaded using Modes $34 and $36.

These three sets of messages are used to perform tests resident in an on-board control module. These messages perform three functions:

Mode $38 - Enter Diagnostic Routine by Address
Mode $39 - Exit Diagnostic Routine by Address
Mode $3A - Request Diagnostic Routine Results

4.24.2 MESSAGE DATA BYTES—(See Figure 31.)

	Data Bytes (Hex)						
	#1	#2	#3	#4	#5	#6 to #n-1	#n
Request from Tool to Vehicle							
Request test entry by starting address	38	Starting Address: high byte	mid byte	low byte	(opt)	Additional optional data bytes may be added to the request to fill the message up to the maximum number of available data bytes.	
Positive Response from Vehicle to Tool (either of the following is a valid response)							
Report entry	78	Starting Address: high byte	mid byte	low byte	(opt)		
General response	7F	Optional data bytes may be included (see Mode $7F description).					Resp. Code - 00
Request from Tool to Vehicle							
Request test exit by starting address	39	Starting Address: high byte	mid byte	low byte	(opt)	Additional optional data bytes may be added to the request to fill the message up to the maximum number of available data bytes.	
Positive Response from Vehicle to Tool (either of the following is a valid response)							
Report exit by starting address	79	Starting Address: high byte	mid byte	low byte	Exit Status (opt)	Additional optional data bytes that are in response to the request may be added to fill the message up to the maximum number of available data bytes.	
General response	7F	Optional data bytes may be included (see Mode $7F description).					Resp. code - 00
Request/Report Diagnostic Routine Results							
Request results	3A	(opt.) Additional optional data bytes may be added to the request to fill the message up to the maximum number of available data bytes.					
Positive Response from Vehicle to Tool							
Report results	7A	Additional optional data bytes that are in response to the request may be added to fill the message up to the maximum number of available data bytes.					

FIGURE 31—MESSAGE DATA BYTES FOR MODES $38 THROUGH $3A

4.25 Mode $3B—Write Data Block

4.25.1 FUNCTIONAL DESCRIPTION—The purpose of this mode is to provide a means for the external test device to change the contents of a data block. The data block numbers and associated memory locations need to be known by the on-board device. This mode does not allow off-board test equipment to change any memory locations other than for those data blocks predefined in the on-board device.

The number of data bytes included in the request message for each block number depends on the system design and intent of the usage for that block.

Possible uses for this mode are:

Clear non-volatile memory
Reset learned values in a single table
Set option content
Set Vehicle Identification Number (VIN)
Change calibration values

This mode can be used to clear or reset tables stored in non-volatile memory. A data block number could be defined as memory locations that need to be either cleared or reset to predefined initial values, such as learned values in a table. Sending the data block number with no data bytes could cause the on-board system to clear/reset all learned values associated with that data block number to known nominal values.

Another use is to allow the VIN to be input. A data block number could be defined to expect a portion of the VIN. Multiple messages would be required to send the entire 17-character VIN. Whatever data values were included in the request message would be stored in the memory locations known by the on-board system for VIN.

In some systems, this mode could be used for programming calibrations or vehicle specific information in the assembly plant or service without using secured methods for reprogramming. If desired that those values not be changed after production, the capability to modify those data blocks could be disabled after the initial change.

4.25.2 MESSAGE DATA BYTES---(See Figure 32.)

	Data Bytes (Hex)			
	#1	#2	#3 to #n-1	#n
Request from Tool to Vehicle				
Request to write data block	3B	Block number	Additional optional data value bytes to be written to memory may be added to fill the message up to the maximum number of available data bytes.	
Positive Response from Vehicle to Tool (either of the following is a valid response)				
Confirm data block written	7B	Block number		
General response	7F	Optional data bytes may be included (see Mode $7F description)		Resp. code - 00

FIGURE 32---MESSAGE DATA BYTES FOR MODE $3B

4.26 Mode $3C---Read Data Block

4.26.1 FUNCTIONAL DESCRIPTION---The purpose of this mode is to provide a means for the external test device to read the contents of a data block. The data block numbers and associated memory locations need to be known by the on-board device. This mode does not allow off-board test equipment to read any memory locations other than for those data blocks predefined in the on-board device.

The number of data bytes included in the Response for each block number depends on the system design and intent of the usage for that block.

Possible uses for this mode are to read:

Learned values in a single table
Option content
Vehicle Identification Number (VIN)
Calibration values

4.26.2 MESSAGE DATA BYTES---(See Figure 33.)

	Data Bytes (Hex)			
	#1	#2	#3 to #n	
Request from Tool to Vehicle				
Request to read data block	3C	Block number		
Positive Response from Vehicle to Tool				
Report contents of data block	7C	Block number	Additional optional data bytes that are in response to the request may be added to fill the message up to the maximum number of available data bytes.	

FIGURE 33---MESSAGE DATA BYTES FOR MODE $3C

4.27 Mode $3F---Test Device Present (no operation performed)

4.27.1 FUNCTIONAL DESCRIPTION---This mode can be used to indicate a tool or test device is present. This message may be required, in the absence of other diagnostic messages, to prevent modules from automatically returning to normal operation. The presence of this message will indicate that the system should remain in a diagnostic mode of operation.

This message will normally be sent to all modules in the vehicle. Because this message is not a specific request for a controller to do something, there is no required response message to the test tool present message. However, if the message strategy includes a response to this, a general response message should be used. If the vehicle contains multiple modules, then multiple responses will be sent, using available data link time.

4.27.2 MESSAGE DATA BYTES---(See Figure 34.)

	Data Bytes (Hex)		
	#1	#2 to #n-1	#n
Request from Tool to Vehicle			
Test tool present	3F		
Positive Response from Vehicle to Tool (optional)			
General response	7F	Optional data bytes may be included (see Mode $7F description).	Resp. Code - 00

FIGURE 34---MESSAGE DATA BYTES FOR MODE $3F

4.28 Mode $7F---General Response Message

4.28.1 FUNCTIONAL DESCRIPTION---Physical requests for information must be responded to by the intended receiver of the request. This message is intended to be a generic response to any request message when data does not need to be returned to the test device. This is an alternative to a specific response when the request is for an action to be performed by the controller. This is also a reject message (negative response) for requests for data or for an action to be performed. See the "Message Response" section for a more detailed discussion about the use of this message.

The response may be an acknowledge that the message was received, or may include a code indicating the reason for rejection if a valid response is not possible. This response assumes that a valid message has been received, and is not intended to inform the sender of an invalid message or to report system failures. Valid response codes are included in this section. Response codes from $00 to $7F are reserved to be defined in this document, and codes from $80 to $FF are reserved to be defined by the vehicle manufacturer.

The format for the general response message is a $7F for the first data byte after the header, optional data bytes that repeat data bytes of the request, and the response code. If a fixed message length is required and there are not enough data bytes in the request, the message should be padded with $00 to fill the remaining data bytes.

4.28.2 MESSAGE DATA BYTES---(See Figure 35.)

	Data Bytes (Hex)				
	#1	#2 to #n-1 (optional)			#n
Response from Vehicle to Tool					
General response	7F	Optional data bytes that repeat data bytes in the request message, in order to uniquely identify the request message, or in order to maintain a common message length, may be inserted between the Mode Value and the Response Code. The last data byte of this message is always the response code.			Resp. Code
	Request Mode value (opt)	Data byte #2 of request (opt)	Data byte #3 of request (opt)	etc.	

FIGURE 35---MESSAGE DATA BYTES FOR MODE $7F

4.28.3 MESSAGE EXAMPLES---Figure 36 shows an example of a Mode $3B request containing 8 data bytes. Four valid general response messages are shown, with others possible to be defined by the vehicle manufacturer. Note that the response code is always the last data byte of the response message.

	Data Bytes (Hex)							
	#1	#2	#3	#4	#5	#6	#7	#8
Example Request from Tool to Vehicle								
Request to write block of memory	3B	Block number	Data value #1	Data value #2	Data value #3	Data value #4	Data value #5	Data value #6
Example Responses from Vehicle to Tool (any of the following is a valid response)								
Simplest form of general response	7F	Resp. Code						
Include test mode value to identify test mode requested	7F	3B	Resp. Code					
Include test mode value and block number requested	7F	3B	Block number	Resp. Code				
Include as much of request message as will fit in response	7F	3B	Block number	Data value #1	Data value #2	Data value #3	Data value #4	Resp. Code

FIGURE 36—GENERAL RESPONSE EXAMPLES

4.28.4 RESPONSE CODES—Figure 37 includes response codes and descriptions to be used with the general response messages

Resp Code	Response Code Description
00	AFFIRMATIVE RESPONSE This response code is used to indicate affirmative response to a request message. It indicates that the requested action will be taken or is already complete.
10	GENERAL REJECT This response code is used to indicate a negative response to a request message. No reason or explanation for the rejection is given.
11	MODE NOT SUPPORTED This response code is used to indicate negative response to a request message. It indicates that the requested action will not be taken because the ECU does not support the requested mode.
12	SUB-FUNCTION NOT SUPPORTED or INVALID FORMAT This response code is used to indicate negative response to a request message. It indicates that the requested action will not be taken because the ECU does not support the arguments of the requested mode or the format of the argument bytes do not match the prescribed format for the specified mode.
21	BUSY -- REPEAT REQUEST This response code indicates that the ECU is temporarily too busy to perform the requested operation. In the circumstance repetition of the request will eventually result in an affirmative response. This code may be returned while an ECU is in the process of clearing stored codes or resetting information. Whenever completion of the requested operation will exceed the maximum response time limit, it is appropriate to use the BUSY -- REPEAT REQUEST message to lengthen the acceptable response period.
22	CONDITIONS NOT CORRECT or REQUEST SEQUENCE ERROR This response code is used to indicate negative response to a request message. It indicates that the requested action will not be taken because the ECU prerequisite conditions are not met. The request may elicit an affirmative response at another time. This code may occur when sequence sensitive requests are issued in the wrong order.
23	ROUTINE NOT COMPLETE This response code is used to indicate that the message was properly received and the routine is in progress, but not yet completed.
31	REQUEST OUT OF RANGE This response code is used to indicate negative response to a request message. It indicates that the requested action will not be taken because the ECU detects the request message contains a data byte which attempts to substitute a value beyond its range of authority (ex: attempting to substitute a data byte of 111 when the data is only defined to 100).

Continued

FIGURE 37—GENERAL RESPONSE CODES

33	SECURITY ACCESS DENIED This response code is used to indicate negative response to a request message. It indicates that the requested action will not be taken because the ECU's security strategy has not been satisfied by the tester.
34	SECURITY ACCESS ALLOWED This response code is used to indicate positive response to a request message. It indicates that the ECU's security strategy has been satisfied by the tester.
35	INVALID KEY This response code is used to indicate negative response to a request message. It indicates that security access has not been given because the ECU's security key was not matched by the tester (this counts as an attempt to gain security access).
36	EXCEED NUMBER OF ATTEMPTS This response code is used to indicate negative response to a request message. It indicates that the requested action will not be taken because the Tester has unsuccessfully attempted to gain security access more times than the ECU's security strategy will allow.
37	REQUIRED TIME DELAY NOT EXPIRED This response code is used to indicate negative response [illegible] indicates that the requested action will not be taken because the [illegible] attempt to gain security access was initiated before the ECU's required [illegible] elapsed.
40	DOWNLOAD NOT ACCEPTED This response code indicates that an attempt to download to an ECU's memory cannot be accomplished due to some fault condition.
41	IMPROPER DOWNLOAD TYPE This response code indicates that an attempt to download to an ECU's memory cannot be accomplished because the module does not support the type of download being attempted.
42	CAN'T DOWNLOAD TO SPECIFIED ADDRESS This response code indicates that an attempt to download to an ECU's memory cannot be accomplished because the module does not recognize the target address for the download as being available.
43	CAN'T DOWNLOAD NUMBER OF BYTES REQUESTED This response code indicates that an attempt to download to an ECU's memory cannot be accomplished because the module does not recognize the number of bytes requested for the download as being available.
44	READY FOR DOWNLOAD This response code indicates that a download to an ECU's memory can be accomplished.
50	UPLOAD NOT ACCEPTED This response code indicates that an attempt to upload from an ECU's memory cannot be accomplished due to some fault condition.
51	IMPROPER UPLOAD TYPE This response code indicates that an attempt to upload from an ECU's memory cannot be accomplished because the module does not support the type of upload being attempted.
52	CAN'T UPLOAD FROM SPECIFIED ADDRESS This response code indicates that an attempt to upload from an ECU's memory cannot be accomplished because the module does not recognize the target address for the upload as being available.
53	CAN'T UPLOAD NUMBER OF BYTES REQUESTED This response code indicates that an attempt to upload from an ECU's memory cannot be accomplished because the module does not recognize the number of bytes requested for the upload as being available.
54	READY FOR UPLOAD This response code indicates that an upload from an ECU's memory can be accomplished.
61	NORMAL EXIT WITH RESULTS AVAILABLE This response code is used to indicate response to a request that the requested test action will be taken, or is already complete [illegible] additional information is available in the form of data, stored codes, or PI

Continued

FIGURE 37—GENERAL RESPONSE CODES (CO

82	NORMAL EXIT WITHOUT RESULTS AVAILABLE This response code is used to indicate response to a request message. It indicates that the requested exit action will be taken, or is already complete, but no additional information is available in the form of data, stored codes, or PIDs.
83	ABNORMAL EXIT WITH RESULTS This response code is used to indicate response to an exit request message. It indicates that the requested exit action will be taken, or is already complete. It is also indicates that the requested execution did not occur in the expected manner and that additional information is available in the form of data, stored codes, or PIDs.
84	ABNORMAL EXIT WITHOUT RESULTS This response code is used to indicate response to a exit request message. It indicates that the requested exit action will be taken, or is already complete. It is also indicates that the requested execution did not occur in the expected manner, but additional information is not available.
71	TRANSFER SUSPENDED This response code indicates that a block transfer operation was halted due to some fault, but will be completed later.
72	TRANSFER ABORTED This response code indicates that a block transfer operation was halted due to some fault, and will not be completed later.
73	BLOCK TRANSFER COMPLETE / NEXT BLOCK This response code indicates that a block transfer operation has been completed successfully.

Continued

FIGURE 37—GENERAL RESPONSE CODES (CONTINUED)

74	ILLEGAL ADDRESS IN BLOCK TRANSFER This response code indicates that the starting address included in the block transfer request message is either out of range, protected, the wrong type of memory for receiving data, or cannot be written to for some reason.
75	ILLEGAL BYTE COUNT IN BLOCK TRANSFER This response code indicates that the number of data bytes included in the block transfer request message is either more than the block transfer can accommodate, requires more memory than is available at the requested starting address, or cannot be handled by the block transfer software.
76	ILLEGAL BLOCK TRANSFER TYPE This response code is used to indicate that the block transfer type included in the request for block transfer is not valid for this application.
77	BLOCK TRANSFER DATA CHECKSUM ERROR This response code is used to indicate that the block transfer data checksum calculated for the block transfer message does not agree with the expected value.
78	BLOCK TRANSFER MESSAGE CORRECTLY RECEIVED This response code is used to indicate that the block transfer message was received correctly, and that any parameters included in the message were valid, but the action to be performed may not be completed yet. This response code can be used to indicate that the message was properly received and does not need to be retransmitted, but the receiving device is not yet ready to receive another block transfer.
79	INCORRECT BYTE COUNT DURING BLOCK TRANSFER This response code indicates that the number of bytes that was expected to be sent was not the same as the number of bytes received.
80 to FF	MANUFACTURER SPECIFIC CODES These response codes are reserved to be specified by the vehicle manufacturer.

FIGURE 37—GENERAL RESPONSE CODES (CONTINUED)

APPENDIX A
DIAGNOSTIC TEST MODE ASSIGNMENTS

A.1 See Table A1.

TABLE A1—DIAGNOSTIC TEST MODE ASSIGNMENTS

Mode	Message Name
00	
01	Request Current Powertrain Diagnostic Data
02	Request Powertrain Freeze Frame Data
03	Request Powertrain Diagnostic Trouble Codes
04	Request to Clear/Reset Diagnostic Trouble Codes
05	Request Oxygen Sensor Monitoring Test Results
06	Request On-Board Monitoring Test Results
07	Request Pending Powertrain Trouble Codes
08	
09	
0A	
0B	
0C	
0D	
0E	
0F	
10	Initiate Diagnostic Operation
11	Request Module Reset
12	Request Diagnostic Freeze Frame Data
13	Request Diagnostic Trouble Code Information
14	Clear Diagnostic Information
15	
16	
17	Request Status of Diagnostic Trouble Codes
18	Request Diagnostic Trouble Codes by Status
19	
1A	
1B	
1C	
1D	
1E	
1F	
20	Return to Normal Operation
21	Request Diagnostic Data by Offset
22	Request Diagnostic Data by PID
23	Request Diagnostic Data by Memory Address
24	Request Scaling and Offset/PID
25	Request to Stop Transmitting Data
26	Specify Setting of Data Rates
27	Data Link Security Access
28	Disable Normal Message Transmission
29	Enable Normal Message Transmission
2A	Request Diagnostic Data Packet(s)
2B	Define Diagnostic Data Packet by Offset
2C	Define Diagnostic Data Packet
2D	
2E	
2F	Input/Output Control by PID
30	Input/Output Control by Data Value ID
31	Request Start Diagnostic Routine by Test No.
32	Request Stop Diagnostic Routine by Test No.
33	Request Diagnostic Routine Results by Test No.
34	Request Download
35	Request Upload
36	Transfer Data

Mode	Message Name
37	Request Stop Data Transfer
38	Request Start Diagnostic Routine by Address
39	Request Stop Diagnostic Routine by Address
3A	Request Diagnostic Routine Results by Address
3B	Write Data Block
3C	Read Data Block
3D	
3E	
3F	Test Device Present - No Operation Performed
40	
41	Report Current Powertrain Diagnostic Data
42	Report Powertrain Freeze Frame Data
43	Report Powertrain Diagnostic Trouble Codes
44	Report Diagnostic Trouble Codes Cleared
45	Report Oxygen Sensor Test Results
46	Report On-Board Monitoring Test Results
47	Report Pending Powertrain Trouble Codes
48	
49	
4A	
4B	
4C	
4D	
4E	
4F	
50	Confirm Diagnostic Operation
51	Confirm Module Reset
52	Report Diagnostic Freeze Frame Data
53	Report Diagnostic Trouble Code Information
54	Confirm Diagnostic Information Cleared
55	
56	
57	Report Status of Diagnostic Trouble Codes
58	Report Diagnostic Trouble Codes by Status
59	
5A	
5B	
5C	
5D	
5E	
5F	
60	Confirm Normal Operation
61	Report Diagnostic Data by Offset
62	Report Diagnostic Data by PID
63	Report Diagnostic Data by Memory Address
64	Report Parameter Offset and Scaling/Mask
65	Confirm Data Stopped
66	Confirm Data Rates Set
67	Confirm Security Access
68	Confirm Normal Message Transmission Disabled
69	Confirm Normal Message Transmission Enabled
6A	Report Diagnostic Data Packet(s)
6B	Confirm Data Packet Defined by Offset
6C	Confirm Data Packet Defined
6D	
6E	
6F	Confirm Input/Output Control by PID
70	Confirm Input/Output Control by Data Value ID
71	Confirm Diagnostic Routine Started by Test No.
72	Confirm Diagnostic Routine Stopped by Test No.
73	Report Diagnostic Routine Results by Test No.
74	Report Download Status
75	Report Upload Status
76	Data Transfer
77	Confirm Data Transfer Stopped
78	Confirm Diagnostic Routine Started by Address
79	Confirm Diagnostic Routine Stopped by Address
7A	Report Diagnostic Routine Results by Address
7B	Confirm Data Block Written
7C	Report Contents of Data Block
7D	
7E	
7F	General Response Message (accept/reject)

OMEGA EXHIBIT 2037

UNIVERSAL INTERFACE FOR OBD II SCAN---SAE J2201 JUN93

SAE Recommended Practice

Report of the Vehicle E/E System Diagnostics Standards Committee and the Vehicle Network for Multiplexing and Data Communications Standards Committee approved June 1993.

TABLE OF CONTENTS

1. Scope
1.1 SAE Document Interrelationships
2. References
2.1 Applicable Documents
2.1.1 SAE Publications
2.1.2 California Air Resource Board Documents
2.1.3 EPA Regulations
2.1.4 ISO Documents
2.2 Terms and Definitions
2.3 Acronyms and Abbreviations
3. Requirements
3.1 Interface and Message Protocol Support
3.2 In-Frame Response
3.3 Signal Ground
3.4 Maximum Voltage Differentials
3.5 Chassis Ground
3.6 Minimum Connector Cable Length
3.7 Other Requirements
4. Interface Functionality Evaluations
APPENDIX A EXAMPLES
A.1 General Example Information
A.1.1 Transient Protection
A.1.2 Host Support Not Included
A.1.3 Supporting Documents
A.1.4 Common ISO 9141-2 Support
A.1.5 Electromagnetic Compatibility
A.1.6 No Responsibility Assumed By Contributors
A.1.7 Additional Capabilities of Examples
A.2 DLCS, HBCC, and ISO 9141-2 Interface Example
A.2.1 General Overview
A.2.2 DLCS Operation
A.2.2.1 Initialization
A.2.2.2 Message Transmission
A.2.2.3 Message Reception
A.2.3 DLCS Pin Names and Descriptions
A.2.4 HBCC Operation
A.2.4.1 Initialization
A.2.4.2 Sending a Message
A.2.4.3 Receiving a Message
A.2.5 HBCC Pin Descriptions
A.2.6 Additional Capabilities
A.3 PCI, HBCC, and ISO 9141-2 Interface Example
A.3.1 General Overview
A.3.2 Control Microcomputer
A.3.2.1 Control Microcomputer Software Structure
A.3.2.2 Control Microcomputer Interface to the Host Microcomputer
A.3.2.3 Control Microcomputer Interface to the SED
A.3.3 Symbol Encoder Decoder (SED)
A.3.3.1 Symbol Encoder
A.3.3.2 Symbol Decoder
A.3.3.3 Invalid Symbol
A.3.3.4 SED Inputs and Outputs
A.3.3.4.1 Transmit Clear (TRCLR~) Input
A.3.3.4.2 Reset (RST) Inputs
A.3.3.4.3 Oscillator (OSC) Input
A.3.3.4.4 Transmit Strobe (TRSTRB) Input
A.3.4 Integrated Driver/Receiver (IDR)
A.3.4.1 Bus Output Waveshaping
A.3.4.2 Transmitting Signals on the Bus
A.3.4.3 Processing Signals Received from the Bus
A.3.5 Additional Capabilities
A.4 SGS-Thomson Protocol Engine Interface Example
A.4.1 General Overview
A.4.2 Control Microcomputer
A.4.2.1 Control Microcomputer Software Structure
A.4.2.2 Control Microcomputer Interface to the Host
A.4.2.3 Automatic OBD II Interface Scan
A.4.3 GAL6001 Programmable Logic Array
A.4.4 Discrete Transceiver
A.4.5 Additional Capabilities
A.5 Silicon Systems F590/F691 Scan Tool Chipset Interface Example
A.5.1 General Overview
A.5.2 F590 Codec
A.5.3 F691 Transceiver
A.5.4 Pin Description
A.5.4.1 F590 Codec Pin Description
A.5.4.2 F691 Transceiver Pinout
A.5.5 Additional Capabilities
A.6 Motorola JCI and ISO 9141-2 Interface Example
A.6.1 General Overview
A.6.2 JCI Operation
A.6.2.1 Host Interface
A.6.2.2 Communication Mode Selection
A.6.2.3 In-Frame Response and I.D. Byte
A.6.2.4 Message Transmission
A.6.2.5 Message Reception
A.6.3 JCI Pin Names and Descriptions
A.6.4 Additional Capabilities
APPENDIX B SUPPORTING DOCUMENTS

1. Scope---SAE J1978 defines the requirements of the OBD II scan tool. SAE J2201 defines the minimum requirements of the vehicle communications interface for the SAE J1978 OBD II scan tool. This interface connects the SAE J1962 test equipment connector to the hardware/software of the SAE J1978 OBD II scan tool that will use this interface to communicate with vehicles for the purpose of accessing required OBD II functions.

Included in this SAE Recommended Practice are several definitions relating to the interface, and interface functionality evaluation.

Appendix A - Examples include several example interface circuit implementations, which are believed to meet the requirements of this document and of SAE J1978. These examples are NOT requirements of this document. They are provided to assist circuit designers in developing interface circuits.

Appendix B - Supporting Documents includes a list of supporting documents for the examples shown in Appendix A.

1.1 SAE Document Interrelationships---Figure 1 shows the interrelationships between SAE J1978, SAE J1962, and this document.

NOTE---See SAE J1962 Diagnostic Connector for pin assignments.

Where any conflict may exist between the requirements contained in SAE J1978 and this document, SAE J1978 is the overriding document.

2. References---The terms, definitions, abbreviations, and acronyms contained in SAE J1930 are included by reference.

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 J1850---Class B Data Communication Network Interface

SAE J1930---Electrical/Electronic Terms, Definitions, Abbreviations, and Acronyms

SAE J1962---Diagnostic Connector

SAE J1978---OBD II Scan Tool

SAE J1979---Diagnostic Test Modes

SAE J2205---Expanded Diagnostic Protocol

2.1.2 CALIFORNIA AIR RESOURCE BOARD DOCUMENTS

California Code of Regulation, Title 13, 1968.1 - Malfunction and Diagnostic System Requirements -- 1994 and Subsequent Model-Year Passenger Cars, Light-Duty Trucks, and Medium-Duty Vehicles With Feedback Fuel Control Systems

2.1.3 EPA REGULATIONS

Federal Register Tuesday September 24,1991, Part II Environmental Protection Agency 40 CFR Part 86 - Air Pollution Control; New Motor Vehicles and Engines: On-Board Diagnostic Systems on 1994 and Later Model Year Light-Duty Vehicles and Light-Duty Trucks; Proposed Rule

2.1.4 ISO DOCUMENTS---Available from ANSI, 11 West 42nd Street, New York, NY 10036-8002.

ISO 9141-2---Road vehicles---Diagnostic systems---CARB requirements for interchange of digital information ISO/TC 22/SC 3/WG 1 - N 425 E/REV April 1991

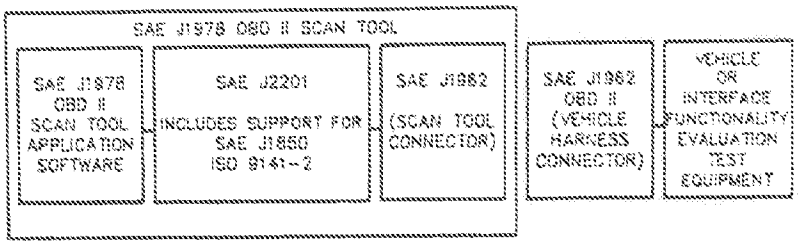


FIGURE 1---SAE DOCUMENT INTERRELATIONSHIPS

2.2 Terms and Definitions

2.2.1 APPLICATION SOFTWARE---As used in this document, this term refers to the microprocessor programming that controls the external equipment/scan tool hardware so as to perform required SAE J1978 OBD II Scan Tool functions.

2.2.2 DLCS---(Data Link Controller Serial) refers to the integrated circuit family developed by General Motors that supports SAE J1850 10.4 Kbps VPW CRC communication.

2.2.3 HBCC---(Hosted Bus Controller Circuit) refers to the integrated circuit developed by Ford Motor Co. that supports SAE J1850 41.6 Kbps PWM CRC communication.

2.2.4 OBD II---(On Board Diagnostics II) common term that refers to the requirements of the California legislation - California Code of Regulation, Title 13, 1968.1.

2.2.5 PCI---(Programmable Communications Interface) refers to a set of integrated circuits which includes a control microcomputer, the Symbol Encoder Decoder (SED) and the Integrated Driver Receiver (IDR). The PCI was developed by Chrysler Corporation and supports SAE J1850 10.4 VPW communication with both CRC and Checksum error techniques.

2.2.6 JCI---(SAE J1850 Communications Interface) refers to an integrated circuit manufactured by Motorola which supports both SAE J1850 10.4 VPW with CRC and SAE J1850 41.6 PWM with CRC communication.

2.3 Acronyms and Abbreviations

CRC - Cyclic Redundancy Check
CS - Checksum
EDP - Enhanced Diagnostic Protocol (SAE J2205)
IBS - Inter-Byte Separation
IFR - In-Frame Response
NRZ - Non Return to Zero
PWM - Pulse Width Modulation
SCI - Serial Communications Interface
SPI - Serial Peripheral Interface
UART - Universal Asynchronous Receiver/Transmitter
VDD - 5.0 VDC from Regulated Power Supply
VPW - Variable Pulse Width Modulation
"~" - Indicates Active Low Signals

3. Requirements---This section defines the required message structure support, signal ground, chassis ground, minimum scan tool connector cable length, and other requirements for the interface to be used by an SAE J1978 OBD II scan tool.

3.1 Interface and Message Protocol Support---The interface defined in this document must support the interface requirements and message protocol requirements of SAE J1978.

3.2 In-Frame Response---When a single byte in-frame response (IFR) is required during the reception of a 41.6 Kbps PWM SAE J1979 message, the interface will support the transmission of the node address as a single byte IFR.

3.3 Signal Ground---The Signal Ground pin of the scan tool side of the SAE J1962 diagnostic connector must be used as the signal ground reference for all interface transceivers required by this document.

3.4 Maximum Voltage Differentials---The interface described in this document includes any required interface transceivers and the cabling connecting the interface transceivers to the scan tool side of the SAE J1962 connector. Any interface connected to a vehicle through the SAE J1962 diagnostic connector is considered a part of the vehicle network and must operate within the limits of that network, which are described in SAE J1850 and ISO 9141-2.

The maximum voltage differential, e.g., due to load current, noise, etc., between any two nodes of a vehicle data communication network, where the interface described in this document is considered as a node on the vehicle network when connected to the vehicle, must be less than the limits specified in SAE J1850 and ISO 9141-2.

The following are maximum voltage differential values for the interface described in this document (as measured between the signal ground connection of all interface transceivers and the Signal Ground pin on the vehicle side of the SAE J1962 diagnostic connector) are:

0.25 V peak noise
0.1 VDC offset

3.5 Chassis Ground---The Chassis Ground pin of the scan tool side of the SAE J1962 diagnostic connector is available for any use, with the exception that the minimum DC impedance between the Chassis Ground and the Signal Ground is 1 MΩ.

3.6 Minimum Connector Cable Length---The minimum length between the ground reference connection of each interface transceiver and the Signal Ground connection of the vehicle side of the SAE J1962 diagnostic connector is 2 m.

3.7 Other Requirements---The interface must support the requirements of SAE J1850, SAE J1962, SAE J1978, SAE J1979, SAE J2205, and ISO 9141-2.

4. Interface Functionality Evaluations---The functionality of any proposed interface implementations must be evaluated by either of the following:

a. The use of multiplex bus interface equipment from I-ME, or equivalent equipment, that with appropriate software simulates vehicles that use the required implementations of SAE J1850 and ISO 9141-2, or
b. The use of representative vehicles of motor vehicle manufacturers that use the required implementations of SAE J1850 and ISO 9141-2.

APPENDIX A
EXAMPLES

A.1 General Example Information---This section shows example interface implementations that are believed to meet the requirements of this document.

These examples are NOT requirements of this document. These examples are intended as an assist to interface circuit designers.

Table A1 illustrates a summary of some of the capabilities available with these examples that are over and above the requirements of this document and some that are required.

TABLE A1—SUMMARY OF CAPABILITIES FOR THE FOLLOWING EXAMPLES

	DLCS & HBCC Section A.2	PCI & HBCC Section A.3	ST9 Section A.4	F680 & F681 Section A.5	J03 Section A.6
Error Checking	CRC	CS & CRC	CS & CRC	CS & CRC	CRC
Comprehends IBS[2]	No	Yes	Yes	Yes	No
Header Bytes	3	1 & 3	1 & 3	1 & 3	3
Generate Break	Yes	Yes	Yes	Yes	Yes
Control Function[3]	No	Yes	Yes	No	No
Host Required	Yes	Optional[1]	Optional[1]	Yes	Yes

Error checking (CS or CRC), IBS, header bytes, and the Break signal are defined in SAE J1850.

1 Host Required refers to the need for a host microcomputer to perform the functionality of SAE J1978. Some interface implementations include a microcomputer as a part of the interface. In some of these implementations, this microcomputer may have enough excess capability so as to also be able to perform "host microcomputer" functions.

2 IBS is part of only 10.4 Kbps VPW networks. It is not a part of 41.6 Kbps PWM networks, nor a part of ISO 9141-2 networks.

3 Control Function refers to parts of an interface that are implemented in software and executed by some form of microcomputer.

A.1.1 Transient Protection—While some of the examples may show transient protection, this document does not specify or require transient protection.

A.1.2 Host Support Not Included—The examples shown here support a nominal type of host interface and are not meant to be directly applicable to any particular host microprocessor, host interface, and/or host software. The host application software (e.g., interface drivers, message building routines, message processing routines, etc.) and/or additional hardware (e.g., signal buffers, signal inverters, clock synchronization circuits, etc.) required to complete the interface to the example circuits shown in this document is the responsibility of the designer/implementer and is not shown here.

A.1.3 Supporting Documents—Appendix B - Supporting Documents identifies documentation that may be used to aid in the understanding of the examples shown in this document.

A.1.4 Common ISO 9141-2 Support—Many of the examples include a common implementation for ISO 9141-2. This common implementation is described here (see Figure 2-D ISO 9141-2).

The ISO 9141-2 document describes the requirements of the ISO 9141-2 interface. This interface is an asynchronous serial communication link using NRZ bit encoding. A 5 bps bit rate is used during module communication initialization and a 10.4 Kbps bit rate is used for all further communications.

This interface includes a K line which is bidirectional and used for all communication phases, and a L line which is output only from the scan tool and is only used during the 5 bps module communication initialization phase. When used to transmit data to a vehicle, both the L and K lines are driven to either ground or battery level, through a 510 Ω resistor, depending on the data value. When used to receive data from a vehicle, the K line is referenced to 1/2 the battery voltage, with a small amount of hysteresis for noise immunity, to determine the logic value of the data being transmitted by a vehicle module.

In all of the examples, the L and K lines are connected to the SCI port of either the host or a control microprocessor. A select signal from the host/control microprocessor is used to enable the L line when necessary.

A.1.5 Electromagnetic Compatibility—The Electromagnetic Compatibility (EMC) characteristics of these examples have not been investigated nor estimated. The ability of the examples to meet EMC or noise radiation requirements is unknown.

A.1.6 No Responsibility Assumed By Contributors—No responsibility is assumed by Chrysler Corporation, Ford Motor Co., General Motors Corporation, Delco Electronics Corporation, SAE, SGS-Thomson, Silicon Systems, Motorola, or any other company for use of any of the examples or products shown in this document nor for any infringements of patents and trademarks or other rights of other parties resulting from the use of these examples or products. No license is granted under any patents, patent rights, or trademarks of the previously named parties.

A.1.7 Additional Capabilities of Examples—Many of the examples support capabilities beyond the requirements of this document. Such capabilities are discussed in a separate section of each example.

A.2 DLCS, HBCC, and ISO 9141-2 Interface Example—This example (see Figure A1a) combines the use of the Data Link Controller Serial (DLCS) integrated circuit developed by Delco Electronics, the Heated Bus Controller Circuit (HBCC) integrated circuit developed by Ford, a discrete 41.6 Kbps transmit driver, and the common ISO 9141-2 interface to provide the required interface support. (Figure A1b shows the detail of the DLCS, Figure A1c shows the detail of the HBCC with its Transmit Driver, and Figure A1d shows the detail for the common ISO 9141-2.)

The DLCS and HBCC communicate with the host through the host's SPI port, while the ISO 9141-2 interface communicates with the host through the host's SCI port. Separate logic interface lines are used by the host to individually select communication between the host and either the DLCS and HBCC, and to enable the L line.

A.2.1 General Overview—The DLCS and HBCC perform as communication peripheral integrated circuits. Following initialization, they isolate the host from bus communications tasks and are only serviced by the host when the host is loading a message for transmission or unloading a received message. The host receives an interrupt when a received message is available and when message transmission is completed. The host only handles communications as full messages. Several control and status registers are available in both the DLCS and HBCC to control their operation and indicate the status of their communications tasks.

This example uses chip select lines from the host to select which peripheral the host wishes to communicate with. Control data from the host enables and disables the DLCS and HBCC interfaces.

Because these devices are available from semiconductor suppliers who are also supplying them to major automotive manufacturers for use in production vehicles, compatibility with those vehicles should be readily verifiable.

The ISO 9141-2 interface is as described in A.1.4. The host uses its SCI interface to communicate with a vehicle through the ISO 9141-2 interface. A logic line is used by the host to enable the L line when necessary.

A.2.3 DLCS Operation—The DLCS contains a logic section and an analog section in a single integrated circuit. The logic section includes the SPI interface to the host, a transmit buffer, a receive buffer, status and control registers, bit timing, and symbol encoding and decoding logic. The analog section includes the transceiver circuitry. Data transfer between the host and the DLCS is done with two byte SPI transfers. The host sends to the DLCS a command byte and a data byte, while the DLCS sends to the host a status byte and a data byte. The content of the data bytes is dependent on the command.

a. Commands sent to the DLCS include:
   (1) General commands (e.g., send break, go to sleep, terminate transmit retry, load configuration data)
   (2) Transmit commands (e.g., load transmit data, transmit message)
   (3) Receive commands (e.g., unload receive data, flush byte, flush message)

b. Status data send from the DLCS indicate the following:
   (1) Receive status (e.g., buffer contains bytes or messages)
   (2) Transmit status (e.g., buffer contains bytes or messages)
   (3) Data link status (e.g., data link shorted)

Operation of the DLCS consists primarily of three functions: initialization, transmission of a message, and reception of a message. Each of these will be discussed in more detail as follows:

A.2.2.1 INITIALIZATION—Initialization is accomplished by sending the DLCS a command byte to load the accompanying data from the host as configuration data. The DLCS can be configured to enable or disable it to interrupt the host, thereby allowing either polling or interrupt based signalling schemes to be used, and to configure the oscillator divisor. Once the DLCS is initialized, normal transmission and reception can begin.

A.2.2.2 MESSAGE TRANSMISSION—Loading a message from the host to the DLCS for transmission on the bus is done by several 2 byte SPI transfers. Each transfer contains a command byte to load the accompanying data as transmit data. Loading the first and last byte of the message must be done with specific command bytes. Once the command to load the accompanying data as the last transmit data byte is received by the DLCS, the DLCS will begin an attempt to transmit the message on the bus. With each 2 byte SPI transfer with the DLCS, a status byte and data byte will be transferred to the host. The status byte is used to determine the status of the transmit buffer, i.e., empty, contains some bytes, full, etc. The status byte also contains receive status. When loading a transmit message into the DLCS, the data bytes returned by the DLCS to the host are ignored.

Page 661 of 1656 OMEGA EXHIBIT 2037

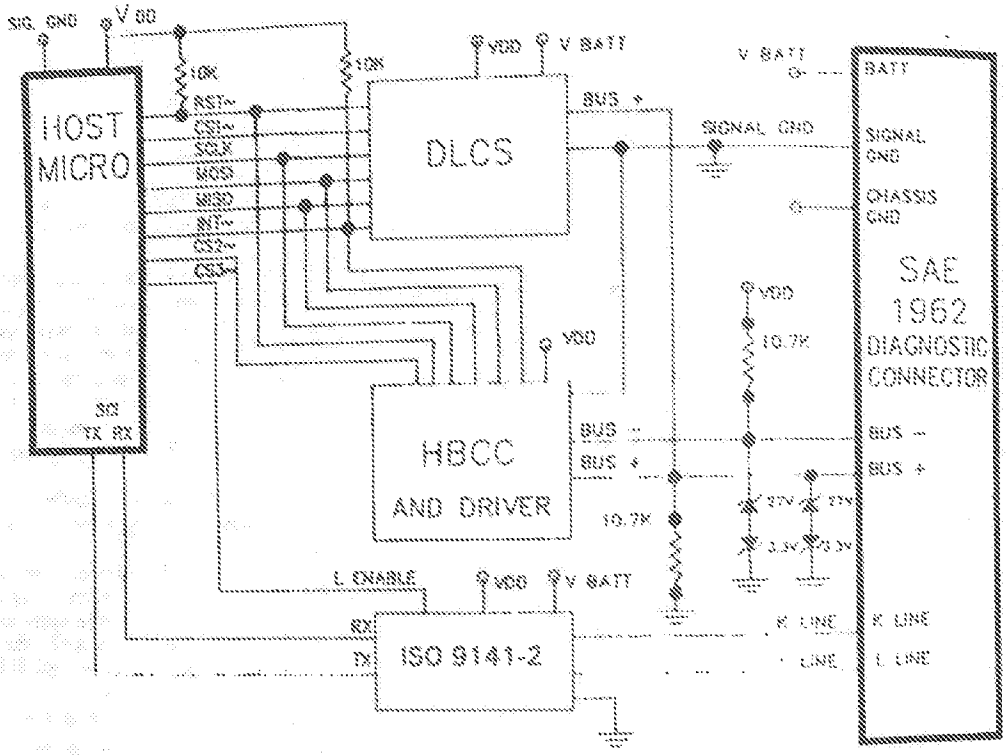


FIGURE A1a—DLCS, HBCC, AND ISO 9141-2 EXAMPLE

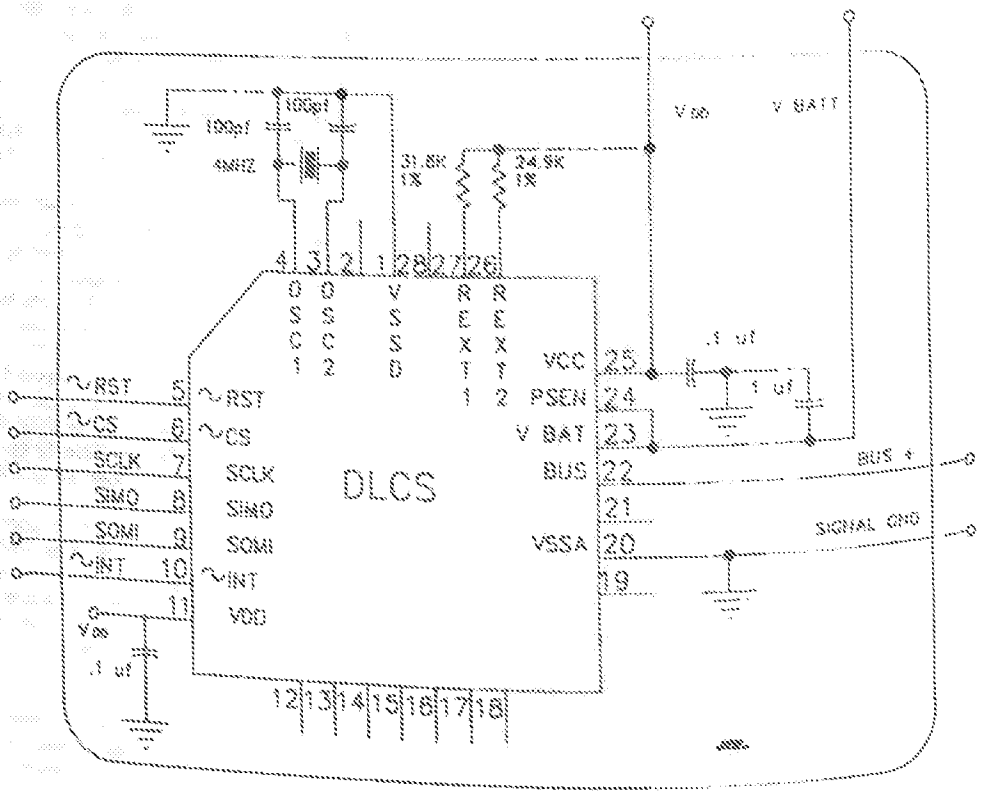


FIGURE A1b—DLCS DETAIL

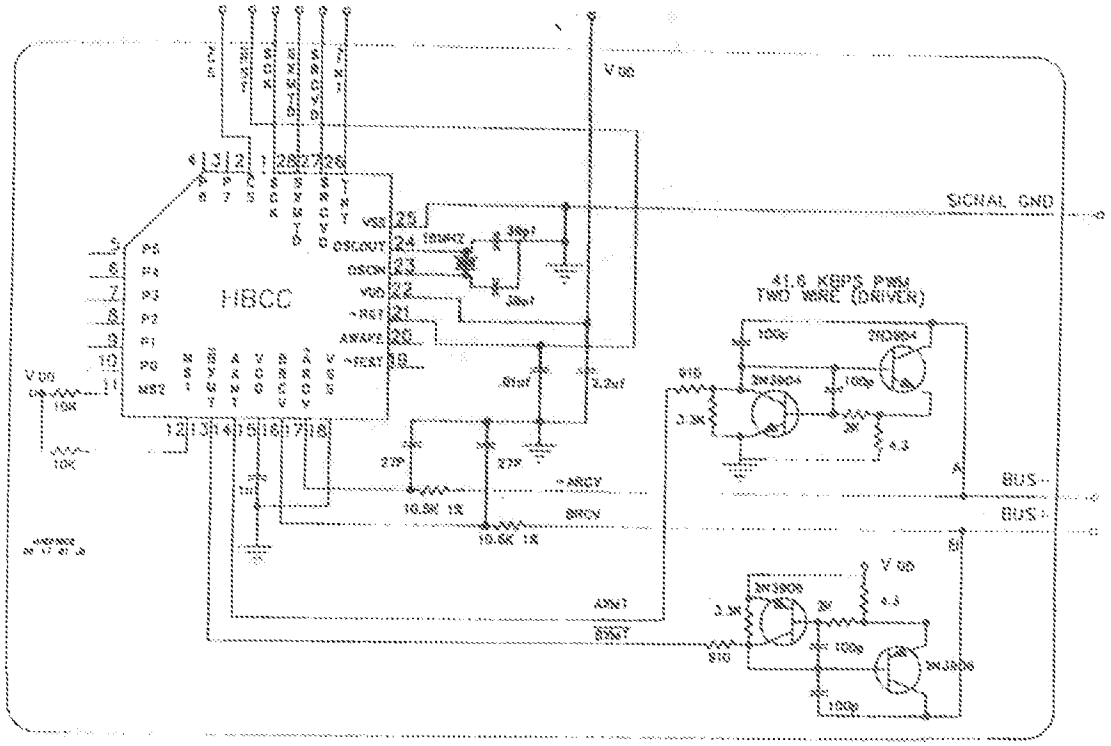


FIGURE A1c—HBCCC AND TRANSMIT DRIVER DETAIL

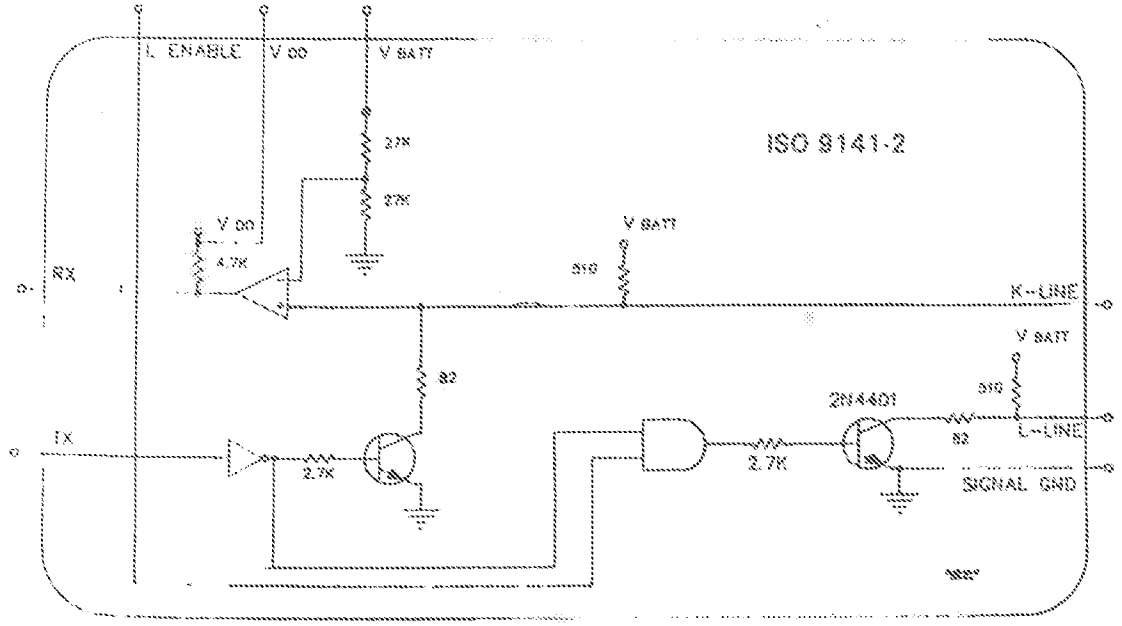


FIGURE A1d—ISO 9141-2 DETAILS

The DLCS handles all data link access responsibilities, i.e., idle bus detection, arbitration, automatic retry (if enabled), etc.

A.2.2.3 MESSAGE RECEPTION—The DLCS on its own receives and buffers a complete message from the bus, checks the received CRC, sets a status flag indicating a message has been received and if any errors occurred and, if enabled, interrupts the host. Retrieving a message received by the DLCS is done first by either polling the DLCS to determine if a message has been received, or by servicing an enabled interrupt that occurs upon reception of a message. (The remainder of this discussion assumes the interrupt method is used.)

Upon receiving an interrupt, performing a 2 byte SPI transfer with the DLCS will result in the transfer of status and data to the host. The status byte is used to determine if the receive buffer contains any bytes of a message or a complete message(s), and the status of the transmit buffer. Once all the bytes of a message have been received by the DLCS an indicator will be set in the status byte and, if enabled, an interrupt will be generated for the host. The status byte will also indicate whether the message was received correctly or that an error occurred, i.e., CRC error, incomplete byte, and bit timing error. If the message uploaded from the DLCS was received while the DLCS was attempting to transmit a message, the status byte will also indicate transmission status values such as overrun or underrun and whether bus arbitration was won or lost.

A.2.3 DLCS Pin Names and Descriptions---The names and descriptions of the pins of the DLCS are shown in Table A2.

TABLE A2---DLCS PIN NAMES AND DESCRIPTIONS

Pin Number	Pin Name	Description
1	Vssd	Digital Ground
2	LOTI	Logic Out Transmitter In (Test)
3	OSC2	Oscillator 2
4	OSC1	Oscillator 1
5	RST-	Reset- (Active Low)
6	CS-	Chip Select- (Active Low)
7	SCLK	SPI Serial Clock
8	SIMO	SPI Slave In Master Out
9	SOMI	SPI Slave Out Master In
10	INT-	Interrupt- (Active Low)
11	Vdd	Digital Voltage Supply (+5 V)
12	N/A	Not Used
13	N/A	Not Used
14	N/A	Not Used
15	N/A	Not Used
16	N/A	Not Used
17	N/A	Not Used
18	N/A	Not Used
19	N/A	Not Used
20	Vssa	Analog Ground
21	LOAD	Bus Load
22	BUS	Bus Output
23	Vbat	Battery Voltage
24	PSEN	Power Supply Enable
25	Vaa	Analog Voltage Supply (+5 V)
26	REXT2	External Resistor 2
27	REXT1	External Resistor 1
28	LITO	Logic In Transmitter Out (Test)

A.2.4 HBCC Operation---The HBCC contains a logic section and an analog section in a single integrated circuit. The logic section of the HBCC supports two types of serial and two parallel host interfaces. This allows for the HBCC to interface with standard Intel or Motorola microprocessors or others which have compatible ports. For this example, the Motorola SPI interface has been used. The logic section also includes a transmit buffer, a receive buffer, status and control registers, bit timing, symbol encoding, and decoding logic. The analog section is limited to the receiver circuitry. The transmitter driver circuit and receiver input noise filter are implemented by external discrete devices.

Data transfer between a host and the HBCC is done with 2 byte SPI transfers. The host transfers an indirect address control byte (ACB) and a data byte to the HBCC. Generally the indirect address points to one of the internal registers of the HBCC and the data sent from the host is stored in the addressed register. During a 2 byte SPI transfer, the host receives a status byte and a data byte from the HBCC. Special address conventions also allow for block type data transfers between the host and the HBCC message buffers.

a. Commands sent to the HBCC include:
   (1) General commands (e.g., initialize node address)
   (2) Transmit commands (e.g., load transmit buffer)
   (3) Receive commands (e.g., read receive buffer)
b. Status data received from the HBCC include the following:
   (1) Receive status (e.g., received byte count)
   (2) Transmit status (e.g., transmission completed OK)
   (3) Network wire status (e.g., network wire shorted)

The operation of the HBCC consists primarily of three functions: initialization, transmission of a message, and reception of a message. Each of these will be discussed in more detail as follows:

A.2.4.1 INITIALIZATION---Initialization is accomplished by sending the HBCC commands to load the accompanying data as configuration information. The HBCC can be configured to enable or disable interrupts to the host, thereby allowing a polling scheme to be used, and to select the bus bit rate. Receive message filter look up tables can also be loaded to screen incoming messages, thus reducing host burden. Once the HBCC is initialized, normal transmission and reception can begin.

A.2.4.2 SENDING A MESSAGE---Loading a message into the HBCC for transmission on the bus is done by several SPI transfers. Each transfer contains an indirect address byte which defines where to store the accompanying data byte into the HBCC transmit buffer. Once the entire message has been loaded into the transmit buffer, the command to transmit the message is sent to the HBCC. The HBCC will then on its own begin to synchronize with the activity on the bus and transmit the message on the bus. The HBCC handles all data link access responsibilities, i.e., idle bus detection, arbitration, and automatic retry. When a message transmit attempt is completed, an interrupt is generated and the host can check the resultant status, including the status of an in-frame response.

A.2.4.3 RECEIVING A MESSAGE---Receiving bus messages using an HBCC is generally based on servicing the interrupt that occurs, if enabled, at the completion of message reception. The HBCC can be configured with interrupts either enabled or disabled, but for this example, interrupts are assumed to be enabled. Upon receiving an interrupt, the host will perform a two byte SPI transfer and receive from the HBCC a status byte and a data byte. The status byte can be used to determine how full the receive buffer is, and whether certain receive errors have occurred. A received message can subsequently be transferred from the HBCC to the host.

A.2.5 HBCC Pin Descriptions---The names and descriptions of the pins of the HBCC are shown in Table A3.

TABLE A3---HBCC PIN NAMES AND DESCRIPTIONS

Pin Number	Pin Name	Description
1	SCLK	Serial Clock
2	CS-	Chip Select- (Active Low)
3	USER7	User Input 7
4	USER6	User Input 6
5	USER5	User Input 5
6	USER4	User Input 4
7	USER3	User Input 3
8	USER2	User Input 2
9	USER1	User Input 1
10	USER0	User Input 0
11	MS2	Mode Select 2
12	MS1	Mode Select 1
13	BXMT-	Network B Drive- (Active Low)
14	AXMT	Network A Drive
15	Vdd	Analog Voltage Supply (+5 V)
16	BRCV	Network B Receive
17	ARCV-	Network A Receive (Active Low)
18	GND	Analog Ground
19	TESTENA-	Test Enable A (Active Low)
20	AWAKE	HBCC Awake
21	RST-	Reset- (Active Low)
22	Vdd	Digital Voltage Supply (+5 V)
23	OSCIN	Oscillator 1
24	OSCOUT	Oscillator 2
25	GND	Digital Ground
26	INT-	Interrupt- (Active Low)
27	SRCVD/SDAT	Serial Data Receive/Serial Data I/O
28	SXMTD/SDIR	Serial Data Transmit/Data Direction

A.2.6 Additional Capabilities---Both the DLCS and HBCC include support for both transmit and receive message buffering and automatic message retransmission. The HBCC also includes support for receive message filtering, wake up, and 41.6 Kbps PWM bus physical layer fault tolerance. The DLCS also includes support to send and receive Break and for wake up.

A.3 PCI, HBCC, and ISO 9141-2 Interface Example---This example (see Figure A2a) combines the use of the Programmable Communication Interface (PCI) developed by Chrysler, the Hosted Bus Communication Controller (HBCC) developed by Ford, a discrete 41.6 Kbps transmit driver, and the common ISO 9141-2 interface to provide the required interface support. (Figure A2b shows the detail of the PCI.)

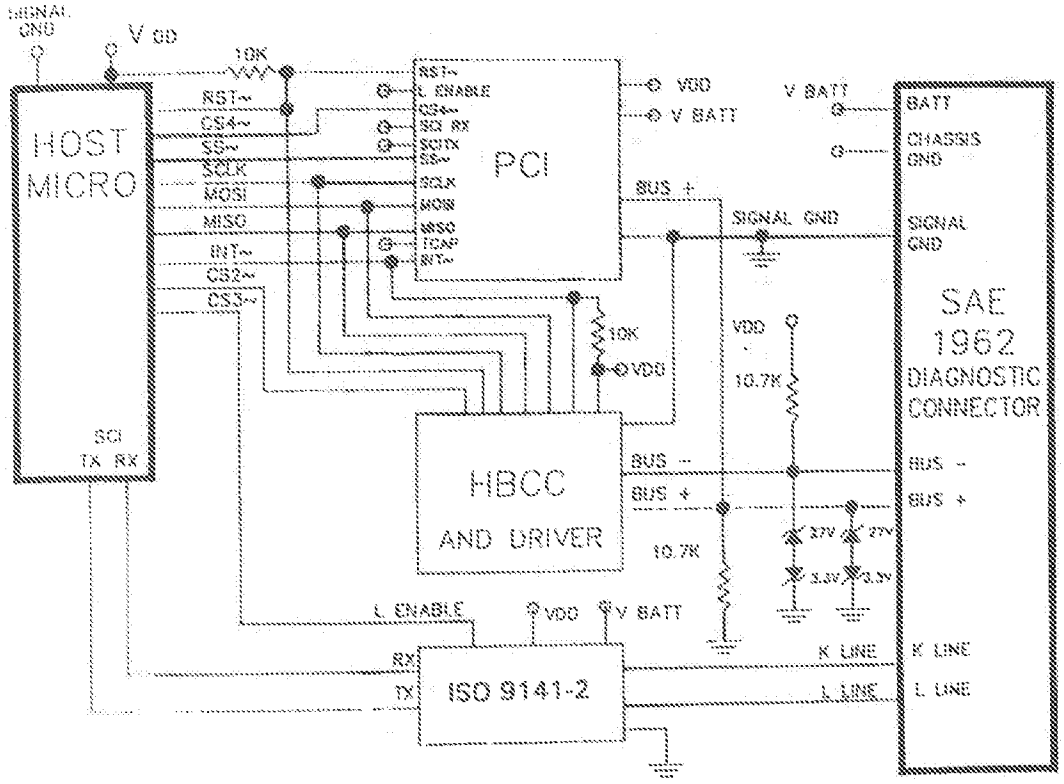


FIGURE A2a—PCI, HBCC, AND ISO 9141-2

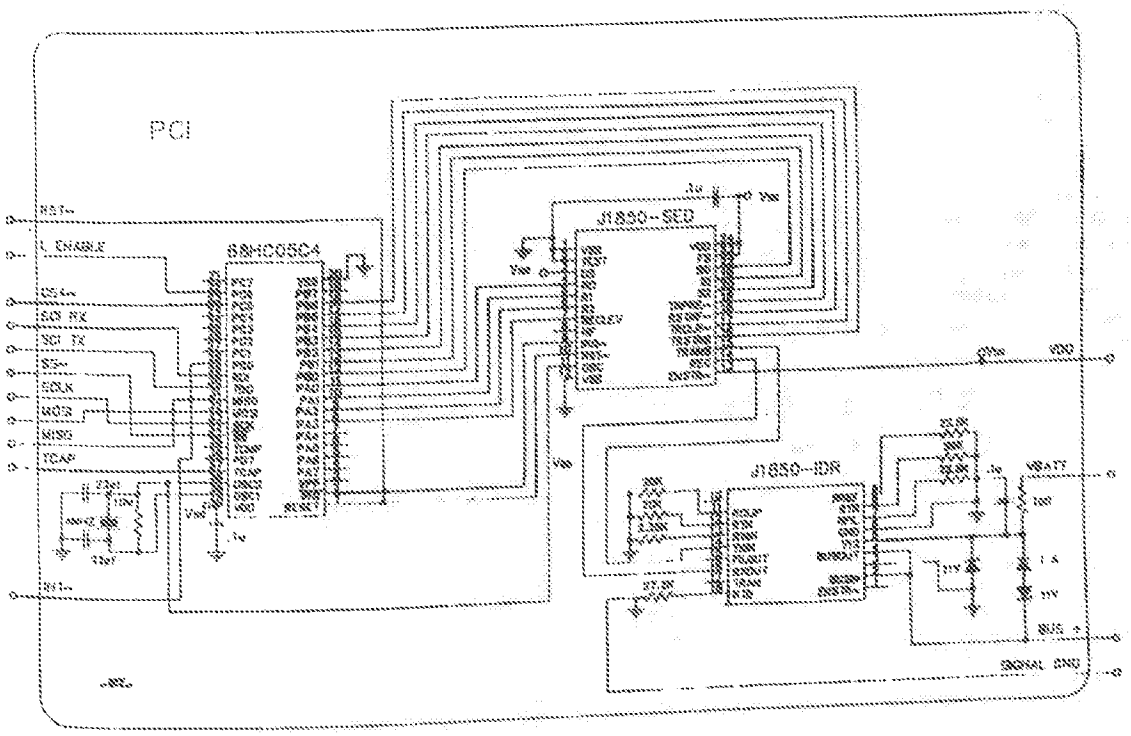


FIGURE A2b—PCI

A description of the HBCC interface is found in A.2.4.

A description of the ISO 9141-2 interface is found in A.1.4.

A description of the PCI is found in this section.

The host communicates with the PCI and the HBCC through the host's SPI interface. The host operates the SPI interface as the master and uses logic control lines to select either the PCI or the HBCC to communicate with. Control information sent from the host to the PCI and the HBCC cause the PCI and HBCC to be enabled or not. The ISO 9141-2 interface uses the SCI interface of the host and a logic line to enable the L line.

A.3.1 General Overview—The PCI operates at a 10.4 Kbps data rate using the symbols specified in SAE J1850.

The PCI is controlled by the coordinated interdependence of both hardware and software. The system consists of the interconnection of three devices:

a. A Control Microcomputer with custom software
b. A Symbol Encoder/Decoder (SED)
c. An Integrated Driver Receiver (IDR)

The control microprocessor controls the operation of the SED and interfaces with the host.

The SED is a digital gate array device which performs symbol encoding and decoding, timing and bus synchronization.

The IDR is an analog ASIC which performs as a 10.4 Kbps VPW bus transceiver for the PCI.

A.3.2 Control Microcomputer—The control microcomputer has overall control of the PCI's operation and interfaces with the host and the SED. The control microcomputer, under software control, interprets host commands and bus symbols.

A.3.2.1 CONTROL MICROCOMPUTER SOFTWARE STRUCTURE—The control microcomputer's most critical task is to service the IRQ interrupts generated by the SED. Less critical tasks are handled on an as-needed basis by the interruptable main program.

The IRQ interrupt processing task services the following:

a. Transmission of Frame Symbols
b. Reception of Frame Symbols
c. Bit-By-Bit Arbitration
d. Error Detection
e. Symbol encoding and decoding
f. In-frame response

The main program services the following:

a. Interface to the host
   (1) SPI (or Parallel) interface service
   (2) Chip selection of control microcomputer by the host
b. Bus calculations
   (1) Checksum or CRC
   (2) Transmit and receive message buffering
   (3) Error interpretation
c. Optional tasks when operating as host also
   (1) Keyboard inputs
   (2) Display drivers

A.3.2.2 CONTROL MICROCOMPUTER INTERFACE TO THE HOST MICROCOMPUTER—The PCI supports both a SPI or a parallel interface with the host. The host functions as interface master for both types of interfaces.

A.3.2.3 CONTROL MICROCOMPUTER INTERFACE TO THE SED—The interface between the control microcomputer and the SED shall be as defined by A.3.3 and Table A4.

TABLE A4—CONTROL MICROCOMPUTER AND SED INTERCONNECTION

Input Port	SED Output	Output Port	SED Input
PA0	R0	PB0	S0
PA1	R1	PB1	S1
PA2	R2	PB2	S2
PA3	RECLEV	PB3	TRPRE-
PA4	NF	PB4	RSTNF
IRQ-	IRQ-	PB5	TRCLR-
		PB6	TRSTRB

A.3.3 Symbol Encoder Decoder (SED)—The SED receives commands from the control microcomputer and converts these commands to SAE J1850 VPW symbols on a symbol-by-symbol bit-by-bit basis. Reception of messages is similarly accomplished, with the SED converting each received symbol into data that is fed to the control microcomputer for deciphering.

A.3.3.1 SYMBOL ENCODER—The control microcomputer initiates the transmission of a frame by first strobing Transmit Preset TRPRE- to a logic "0" and strobing Transmit Strobe TRSTRB to a logic "1". The S0, S1, and S2 Inputs are then set to the logic levels defined in Table A5 in order to activate the transmit symbol generator circuit. During each symbol, the Transmit Strobe TRSTRB is strobed. The transmit symbol generator produces the required symbol on the Transmit TRANS Output of the SED. When the symbol has completed transmission, the SED Receive Circuit generates an IRQ- interrupt to the control microcomputer to obtain the next symbol. This cycle is repeated until the entire frame is transmitted.

TABLE A5—TRANSMIT SYMBOL DEFINITION

Inputs S2	Inputs S1	Inputs S0	Output Description J1850 Xmit Symbol
0	0	1	Tv1 Short
0	1	0	Tv2 Long
0	1	1	Tv3 SOF or EOD
1	0	0	Tv4 IFS
1	0	1	Tv5 IBS
1	1	0	>Tv6 BREAK

A.3.3.2 SYMBOL DECODER—Similarly to the operation of the symbol encoder, the completion of the reception of a symbol from the IDR by the SED causes the SED to interrupt the control microcomputer. The control microcomputer reads the SED's R0, R1, and R2 outputs to determine which symbol was received, as defined by Table A6.

The meaning of each received VPW symbol is dependent on whether the symbol level is dominant or passive. This level is read by the control microcomputer on the Receive Level RECLEV Output of the SED.

TABLE A6—RECEIVE SYMBOL DEFINITION

Outputs R2	Outputs R1	Outputs R0	Input Description J1850 Rec. Symbol
0	0	0	Invalid Symbol
0	0	1	Tv1 Short
0	1	0	Tv2 Long
0	1	1	Tv3 SOF or EOD
1	0	0	Tv4 EOF
1	0	1	Tv4 IFS
1	1	0	Tv5 IBS

A.3.3.3 INVALID SYMBOL—The reception of an Invalid Symbol (Refer to Table A6) sets a Noise Flag NF Output. This Output remains at a logic "1" level until cleared by Reset Noise Flag RSTNF Input.

A.3.3.4 SED INPUTS AND OUTPUTS—All inputs and outputs from the SED are at standard CMOS voltage levels.

The following discusses some particular SED inputs and outputs.

A.3.3.4.1 Transmit Clear (TRCLR-) Input—The SED's TRCLR- Input can be used by the control microcomputer to terminate the transmission of a IBS or Break symbol. IBS may be terminated after the minimum Tv5 period has been generated and a Break symbol may be terminated after a period greater than the maximum Tv5 has been generated.

A.3.3.4.2 Reset (RST) Input—The RST Input to the SED is used to initialize the SED.

A.3.3.4.3 Oscillator (OSC) Input—The OSC Input to the SED is the Time Base Clock Signal. When the DS Input is connected to VCC, a 4.0 MHz clock is required. When DS Input is grounded, an 8.0 MHz clock is required.

A.3.3.4.4 Transmit Strobe (TRSTRB) Input—The TRSTRB Input to the SED operates as a watchdog circuit to insure that the control microcomputer is functioning correctly. The TRSTRB Circuit requires that each transmit symbol must be strobed into the SED or the SED will transmit an idle Output. The TRSTRB Input is active when ENTRSTRB Input is grounded and disabled when the ENTRSTRB Input is connected to VCC.

Page 666 of 1656 OMEGA EXHIBIT 2037

A.3.4 Integrated Driver/Receiver (IDR)—The IDR is the interface between the vehicle bus wiring and the SED. The IDR integrates and simultaneously performs both the bus driver and receiver functions. The bus output waveform is specifically shaped to conform to SAE J1850 requirements and to minimize EMI.

A.3.4.1 Bus Output Waveshaping—The IDR bus output is wave shaped to have symmetrical rise and fall voltage waveforms within the range of allowed bus loading tolerances and battery operating voltages and during message arbitration. The waveshaping consists of a set rise/fall and corner rounding times. The maximum rise/fall time is 16 µs with the corner rounding of 4 µs. The typical rise/fall time is set to 14 µs with corner rounding of 3 µs.

A.3.4.2 Transmitting Signals on the Bus—The IDR receives 1's and 0's from the SED on the CMOS compatible Transmit pin (Tx) and translates these to wave shaped high and low signals at the bus out pin (Bout). The propagation delay between the transition on the Tx pin and the corresponding transition on the Bout pin measured at 3.875 V is a maximum of 12 µs, with a typical value of 10 µs.

A.3.4.3 Processing Signals Received from the Bus—The IDR receives 1's and 0's on the bus input pin (Bin) and translates these to 1's and 0's at the CMOS compatible Receive pin (Rx). The propagation delay between the transition on the Rx pin and the corresponding transition on the Bin pin measured at 3.875 V is a maximum of 2 µs, with a typical value of 1 µs.

A.3.5 Additional Capabilities—The additional capabilities of the HBCC are shown in A.2.6.

The PCI is able to buffer both transmit and receive messages, send and receive Break, support both CRC and Checksum for message error checking, and comprehend IBS.

The MPU used in this example for the control microcomputer is a Motorola 68HC05C4. This particular version of the 68HC05 family is used for the designer's convenience. A much simpler 68HC05P7 microcomputer could also be used to perform the required PCI control tasks and in some cases the host tasks of a scan tool. The 68HC05C4's utilization during message transmission averages about 50% of the available CPU time. It is likely that with so much CPU time still available, the 68HC05C4 or the more powerful and faster 68HC11 could be used to perform both the control and host tasks.

A second example in this section (see Figure A3) shows the use of the control microprocessor associated with the PCI as the host also. As such the control microcomputer is connected to the HBCC and ISO 9141-2 interfaces. The external equipment manufacturer is left to design the interface to any required keyboard and display, which are not shown. Similarly to the case shown in Figure A2a, the control microcomputer externally selects the HBCC or the ISO 9141-2 interface when needed.

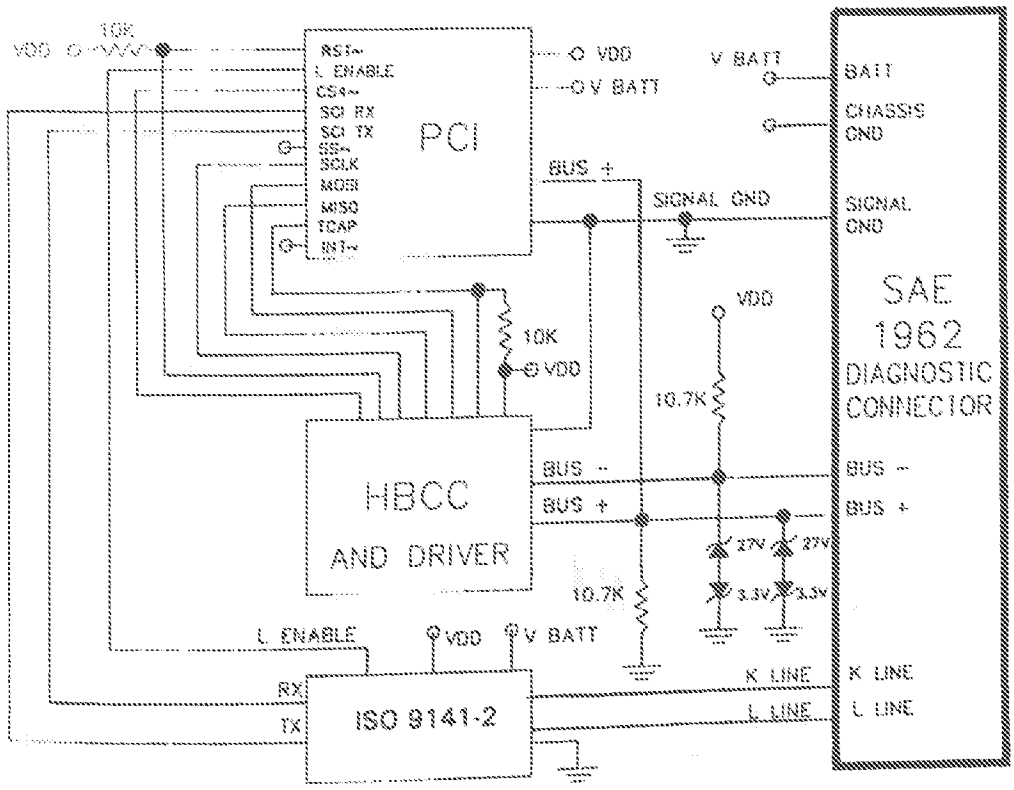


FIGURE A3—PCI, HBCC, AND ISO 9141-2 WITH PCI AS HOST ALSO

A.4 SGS-Thomson Protocol Engine Interface Example—This example (see Figure A4a) combines the use of an SGS-Thomson ST9 microprocessor as a control microcomputer, control microprocessor software, a GAL6001 programmable logic array device and discrete bus transceiver circuitry to provide the required interface support. Together these devices are identified as the SGS-Thomson Protocol Engine. (Figure A4b shows the detail of the ST9 and the GAL6001, Figure A4c shows the detail of the 10.4 Kbps Transceiver, Figure A4d shows the detail of the 41.6 Kbps Transceiver, and Figure A4e shows the detail of the ISO 9141 Transceiver.)

In this example the host microcomputer is connected to only one interface, the Protocol Engine. The Protocol Engine directly supports the required SAE J1850 and ISO 9141-2 interfaces and includes the ability to, on its own, determine the particular interface being used by a vehicle to support OBD II communication.

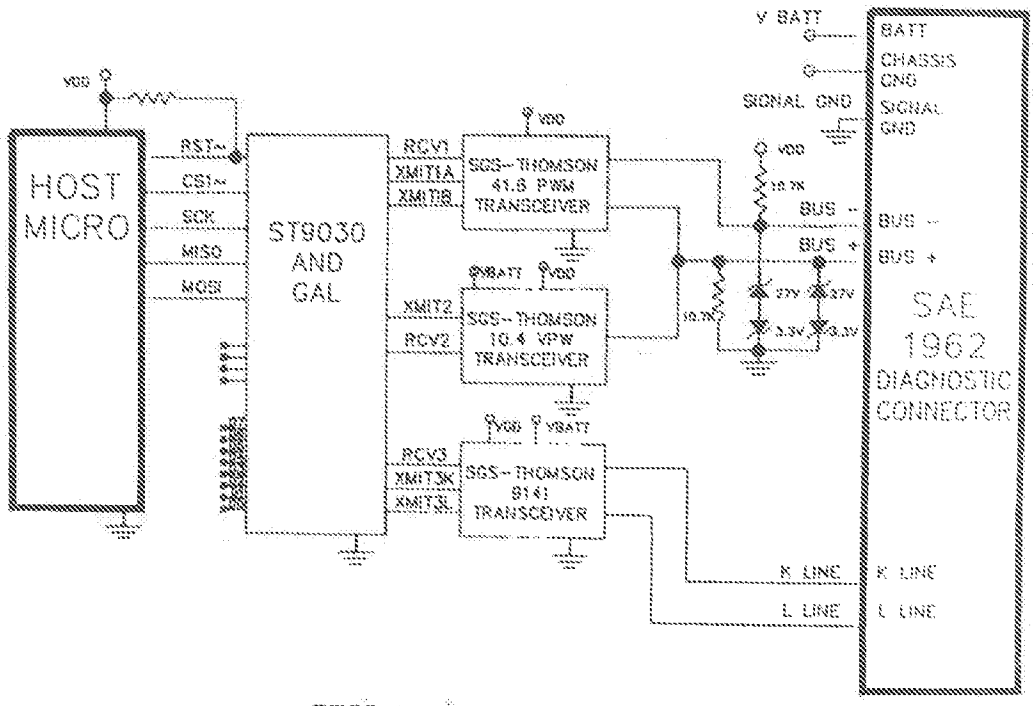


FIGURE A4a—SGS-THOMSON PROTOCOL ENGINE

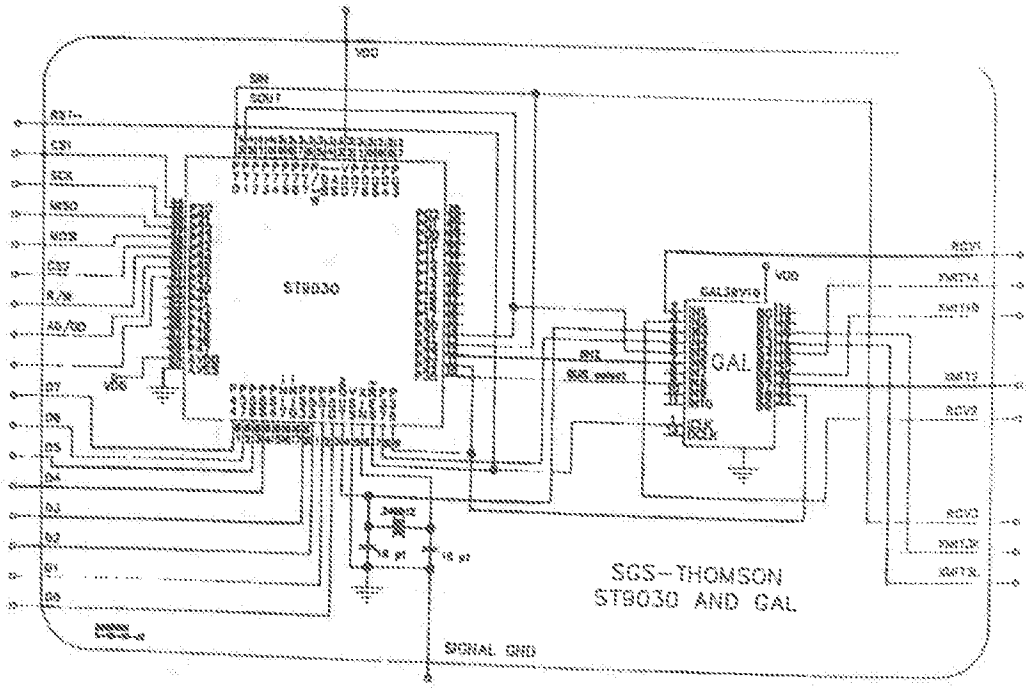


FIGURE A4b—SGS-THOMSON ST9030 AND GAL

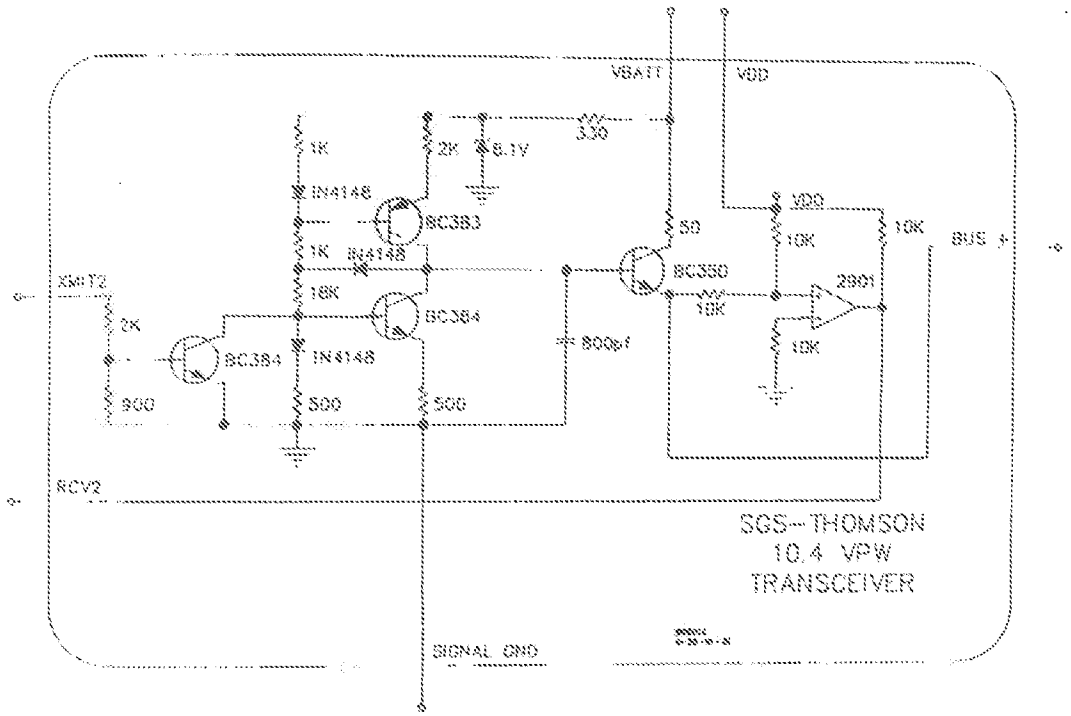


FIGURE A4c—SGS-THOMSON 10.4 VPW TRANSCEIVER

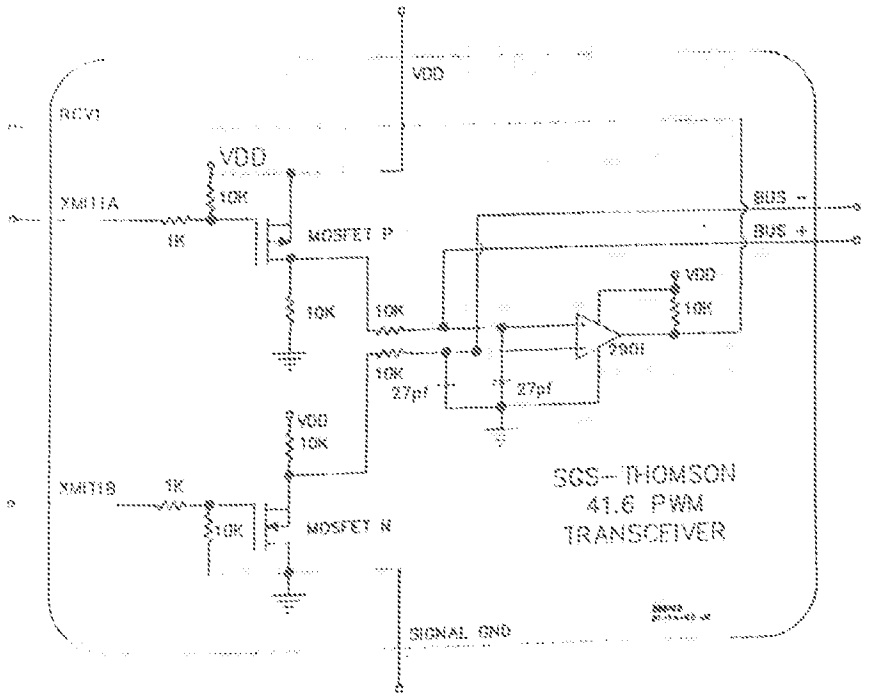


FIGURE A4d—SGS-THOMSON 41.6 PWM TRANSCEIVER

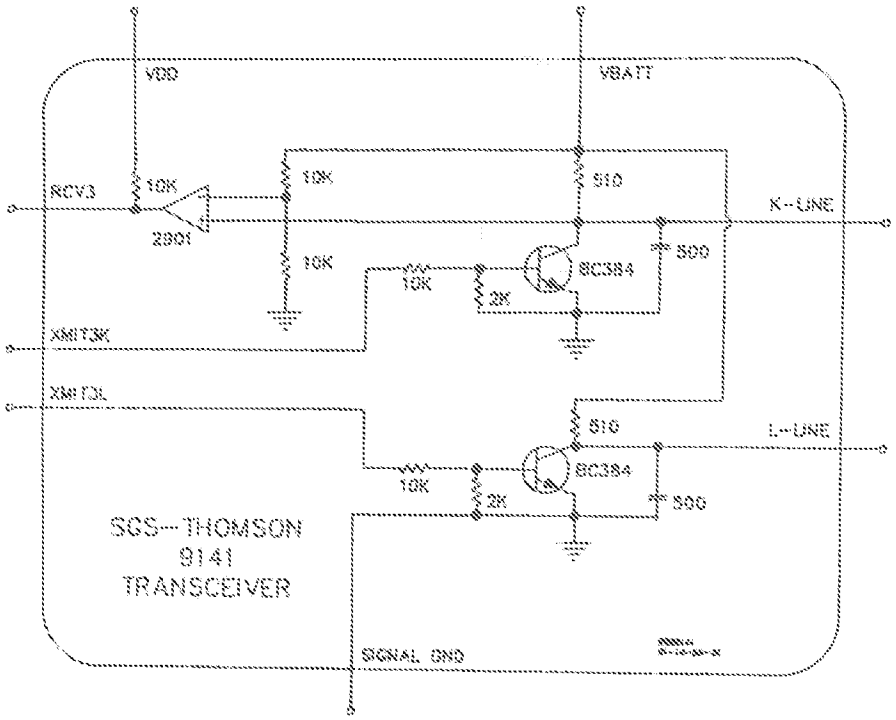


FIGURE A4e—SGS-THOMSON 9141 TRANSCEIVER

A.4.1 General Overview—As mentioned in Section A.4, the Protocol Engine is comprised of four parts: the ST9 control microcomputer, control microcomputer software, the GAL6001 programmable logic array device, and several discrete transceivers.

A.4.2 Control Microcomputer—A SGS-Thomson ST9 family microcomputer is used as an interface control microcomputer. The ST9 microcomputer is a general purpose 8/16 bit microcomputer. Its timer facilities are used extensively to provide the control of transmitted waveforms and the detection of received signals.

Both SPI and parallel interfaces to host microcomputers are supported.

The host can request the Protocol Engine to either scan the possible OBD II interfaces and determine the type used in a given vehicle or use a selected interface type.

A.4.2.1 CONTROL MICROCOMPUTER SOFTWARE STRUCTURE—The highest priority tasks in the control microcomputer support the symbol-by-symbol processing of each transmitted and received message frame. The control microcomputer, and in particular the ST9's timers, directly controls the rise and fall of transmitted signals and directly follows the rise and fall of received signals. When transmitting a message, it performs both of these processes simultaneously. All other control microcomputer tasks are processed on a time available basis.

The following further identifies the control microcomputer's tasks:

a. Highest Priority Tasks:
   (1) Bus synchronization
   (2) Transmission and reception of frame symbols
   (3) Bit-by-bit arbitration
   (4) Comprehension of IBS
b. Background tasks:
   (1) CRC or checksum calculation
   (2) Symbol encoding and decoding
   (3) Message buffering
   (4) In-frame response processing
   (5) Error checking
   (6) Host interface

A.4.2.2 CONTROL MICROCOMPUTER INTERFACE TO THE HOST—Communication between the control microcomputer and the host is based on the host reading from and writing to 64 bytes of memory in the control microcomputer. Sixteen bytes are reserved for status and control of SAE J1850 related operations, 13 bytes are reserved for status and control of ISO 9141-2 related operations, 3 bytes are reserved for general status and control, and 32 bytes are reserved for receive and transmit buffers and related pointers and counters.

Data transfers between the host and the control microcomputer are performed as 2 byte transfers, a control byte and a data byte, initiated by the host. The control byte from the host indicates whether the host wishes to read or write a byte in the control microcomputer and what the address of the byte is (see Figure A5). The second SPI byte transfer moves the byte read from the control microcomputer to the host or the byte to be written from the host to the control microcomputer.

The control microprocessor supports both an SPI and a parallel type of interface with the host. In order to properly service bus communications, the control microcomputer controls the actual data transfers between itself and the host.

A.4.2.3 AUTOMATIC OBD II INTERFACE SCAN—Upon host request, the Protocol Engine will, by itself, automatically scan all of the possible OBD II interfaces and determine the one supported by a given vehicle. The interface scan sequence used is as follows:

a. SAE J1850 41.6 Kbps PWM
b. SAE J1850 10.4 Kbps VPW
c. ISO 9141-2

A.4.3 GAL6001 Programmable Logic Array—The GAL6001 Programmable Logic Array performs primarily as a digital filter of the signal received from the vehicle bus. It is a standard high-performance field programmable EEPROM logic device and is available in a variety of packages. The device chosen has a 20-year data retention specification. It is organized as a 78 X 64 X 36 FPLA.

A.4.4 Discrete Transceives—The discrete transceiver circuitry includes all the components necessary to create the required transmit signal waveforms on a bus and to receive bus signals. This includes support for 41.6 PWM, 10.4

VPW and ISO 9141-2. The transceiver is responsible for or controls the following:

a. Voltage on the bus
b. Current levels
c. Media impedance
d. Signal rise times and fall times

The overall signal transmitted by the transceiver is controlled by the control microcomputer. Signal transmission on a bus is created through the use of current sources/sinks. The 10.4 Kbps VPW driver is comprised of a current source of 1X magnitude and a current sink of 2X magnitude. By switching on and off the 2X current sink, the transceiver effectively causes the bus to make transitions from zero to one to zero. The current sinked or sourced into the bus capacitance controls the rise and fall times of the signals. The control microcomputer controls the "ON" and "OFF" timing of the 2X sink, thereby controlling the data and data rate on the bus.

80	7	6	5	4	3	2	1	0
	R/W	R*	MSB	6 bits of address				LSB

R/W = Read/Write command bit. 0 = write to ST9
1 = read from ST9

R* = Reset. 0 = Resets the chip.

6 bits of address = address to read/write

FIGURE A5—PROTOCOL ENGINE COMMAND BYTE

By using the controlled current sink and source approach this driver effectively becomes short-circuit proof.

A.4.5 Additional Capabilities—In addition to supporting the requirements of this document, the Protocol Engine also supports the following options of SAE J1850: Checksum, comprehend IBS, Single Byte Header, and Break.

Being software driven, the control microcomputer can be considered for supporting additional custom interfaces to test equipment host microcomputers.

Simulation has determined that the bus signal control and monitor tasks require less than 30% of the control microcomputer leaving at least 70% of a very fast microcomputer available for the other tasks such as performing as the host.

Other facilities that are available with various versions of ST9 microcomputers are:

a. Eight 8-bit analog-to-digital channels
b. Eight user readable input pins
c. Eight user writable output pins

The analog to digital support would allow the host to have the control microcomputer to do such things as determine if the diagnostic connector is plugged in, and look at the voltages on the bus and determine if communication is possible.

ST9 microcomputer models have support for up to 32K of ROM or up to 16 megabytes of external memory.

The ST9030 shown in this example is the lowest member in the ST9 family currently available, therefore all members of the ST9 family can support OBD II communication.

A.5 Silicon Systems P690/P691 Scan Tool Chipset Interface Example—This example (see Figure A6a) combines the use of the P690 Codec and P691 Transceiver scan tool chip set developed by Silicon Systems (SSI) to provide the required interface support. (Figure A6b shows the detail of the P690 Codec, and Figure A6c shows the details of the P691 transceiver.)

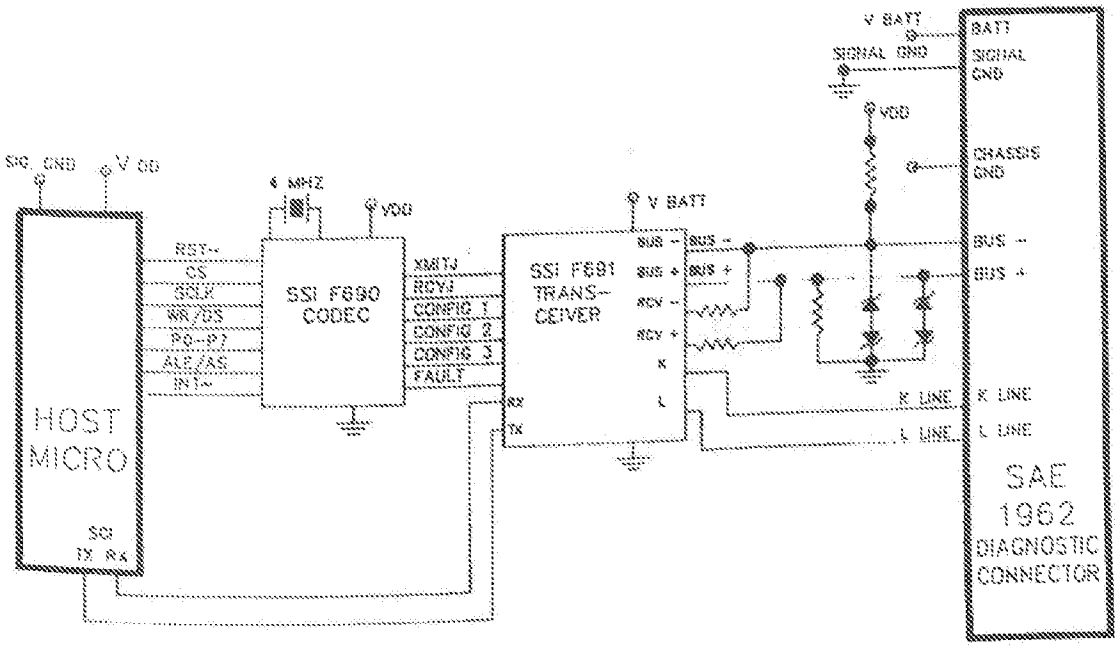


FIGURE A6a—SILICON SYSTEMS P690/P691 CHIPSET

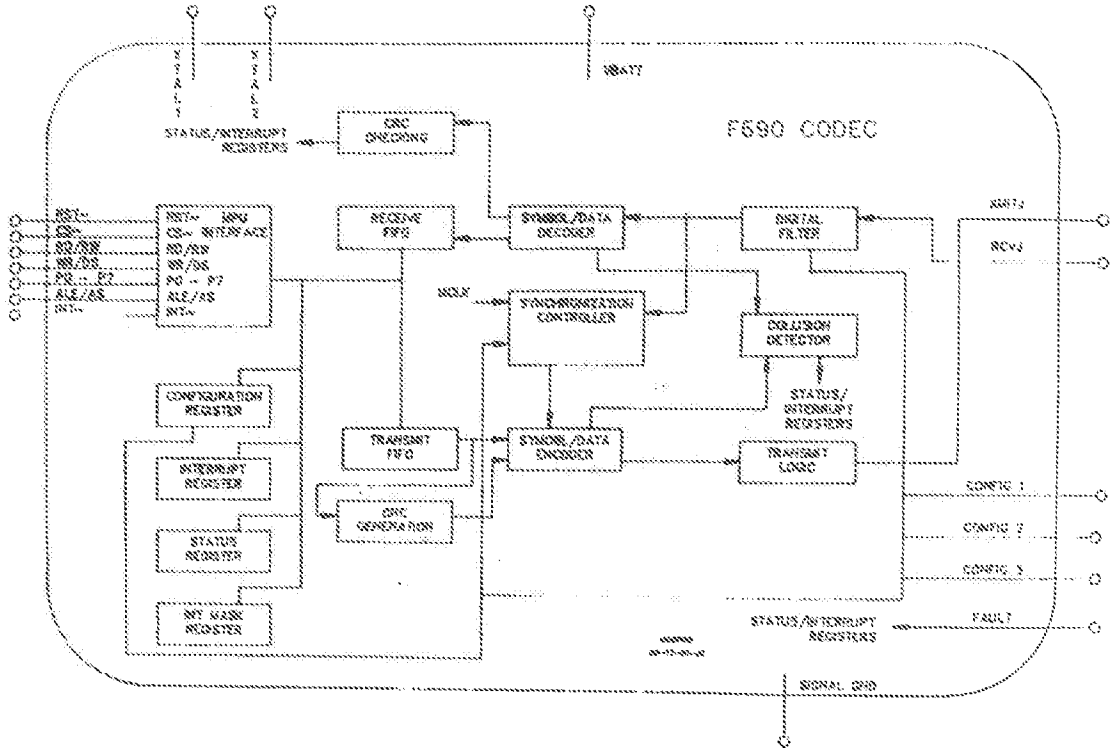


FIGURE A6—F690 CODEC

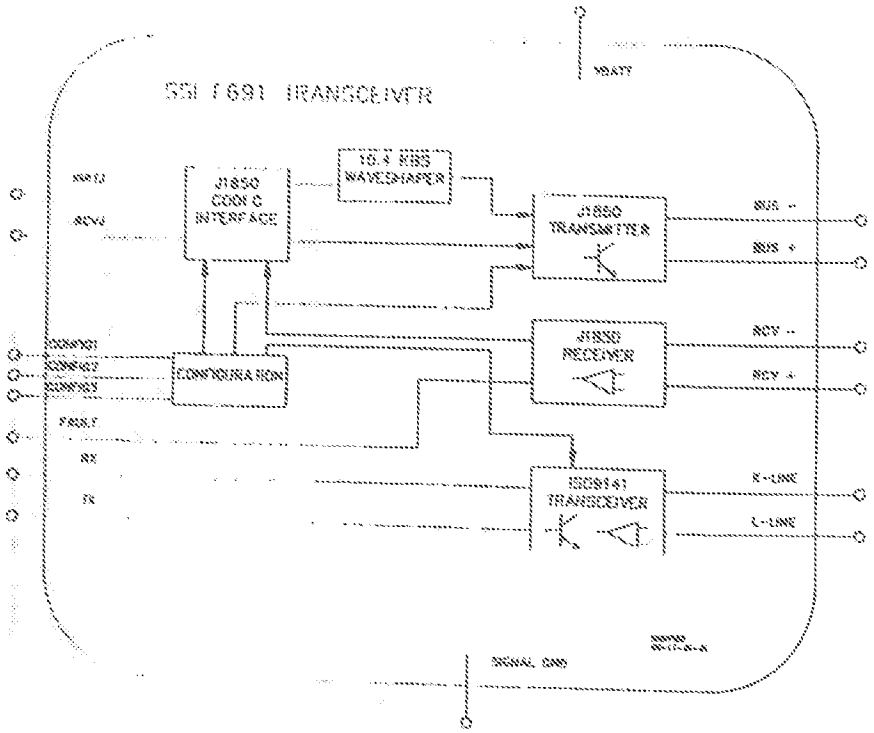


FIGURE A6—F691 TRANSCEIVER

A.5.1 General Overview—The SSI Scan Tool chipset consists of the F690 Codec and the F691 Transceiver. The F690 Codec performs the bit/symbol level CODer/DECoder operations for the SAE J1850 interfaces. This allows the host processor to communicate with the chipset at the byte level. A parallel type interface is used between the host and the Codec.

The F691 Transceiver performs the physical interface for the SAE J1850 41.6 Kbps PWM, SAE J1850 10.4 Kbps VPW, and ISO 9141-2 requirements.

The ISO 9141-2 interface support of the Transceiver is directly connected to the SCI interface of the host.

A.5.2 F690 Codec—A functional block diagram of the F690 Codec chip is shown in Figure A6b. The Codec interfaces with the host processor via an 8-bit parallel bus. The bus is multiplexed and both Motorola and Intel microcomputer parallel type interfaces are supported. Reset, chip select, and interrupt line connections are also used.

Transmit bytes are loaded from the host into the Transmit FIFO buffer of the Codec, which also performs a parallel to serial conversion. The bit serial output from the Transmit FIFO is input into the symbol encoder as well as into the CRC generation logic. The symbol encoder converts bits (1 or 0) into the appropriate PWM/VPW timing symbols. Transmitted symbols are synchronized to the received data. The transmit logic controls the output that drives the F691 Transceiver.

The framing symbols for SOF, IBS, EOD, NB, EOF, and IFS are also generated by the Codec. The host only needs to pass to the Codec the message bytes, and checksum, when used.

The F690 Codec receives information from the F691 Transceiver chip via the RCVJ input pin. The receive input from the Transceiver is, in the Codec, digitally filtered and fed into the symbol decoder. Transitions at the digital filter output are also used to synchronize the transmitter. The collision detect logic compares the transmitted and received signals and performs the bus arbitration function.

The symbol decoder compares the digital filter output with known symbol templates. When a data bit match occurs, the proper bit (1 or 0) is shifted into the receive FIFO buffer. When framing symbols are detected, they are stripped from the received data and fed into the synchronization/controller logic. The data values from the symbol decoder output are also fed into the CRC checking logic. The receive FIFO buffer also performs a serial to parallel conversion such that the host processor can parallel read a received data byte.

Configuration data, transmit and receive status data, and interrupt mask registers are included on the F690 Codec. Interrupts can be enabled to indicate transmit buffer empty, receive buffer full, CRC error, lost arbitration, idle bus, fault detection, etc.

The F690 Codec chip is available in a 28 PLCC package. The part is fabricated in a CMOS technology, operates from a 5 V supply, and consumes less than 100 mW max.

A.5.3 F691 Transceiver—A functional block diagram of the F691 Transceiver is shown in Figure A6c. This chip performs the physical level interface functions. The Transceiver is capable of driving a single-ended, waveshaped, 10.4 Kbps VPW signal as well as the differential, 41.6 Kbps PWM signal onto SAE J1850 buses. Two configuration lines from the F690 Codec determine what xmit/receive mode is to be used by the Transceiver. The receiver consists of either single-ended or differential comparators. Hysteresis is added to improve noise immunity. The transmitter/receiver for the ISO 9141-2 interface is also included on the Transceiver.

Other than waveshaping for the SAE J1850 10.4 Kbps VPW interface, all timing is controlled by the F690 Codec chip. An on-chip bandgap reference and prepackage trims are used to tightly control the SAE J1850 10.4 Kbps VPW waveshape parameters and comparator switching levels.

The F691 Transceiver chip is available in a 16-pin plastic DIP. The part is fabricated in a BIPOLAR technology, operates from a single 9 to 13 V supply, and dissipates 500 mW max.

A.5.4 Pin Descriptions—The pin numbers are not finalized. This section describes pin function only.

A.5.4.1 F690 CODEC PIN DESCRIPTION—The names and descriptions of the pins of the F690 Codec are shown in Table A7.

A.5.4.2 F691 TRANSCEIVER PINOUT—The names and descriptions of the pins of the F691 Tranceiver are shown in Table A8.

TABLE A7—F690 CODEC PIN NAMES AND DESCRIPTIONS

Pin Number	Pin Name	Description
1	VDD	positive supply voltage, +5 V
2	GND	ground
3	XTAL1	4 MHz crystal connection; can be driven by an external clock
4	XTAL2	4 MHz crystal connection
5	CLKOUT	buffered output clock
6	CS	chip select, digital input, active low
7	RD/RW	digital input, Intel/MOTO processor interface control
8	WR/DS	digital input, Intel/Moto processor interface control
9	ALE/AS	digital input, Intel/Moto address strobe
10	INT	digital output, interrupt, active low
11	RST	digital input, reset
12	XMITJ	digital output, SAE J1850 xmit signal
13	RCVJ	digital input, SAE J1850 receive signal
14	XMITJ	digital output, SAE J1850 xmit signal
15	BUSEL	digital input, Intel/Motb bus select
16	CONFIG1	digital output, configuration bit for F691 Transceiver
17	CONFIG2	digital output, configuration bit for F691 Transceiver
18	CONFIG3	digital output, configuration bit for F691 Transceiver
19	N/A	
20	N/A	
21-28		digital I/O, bus interface P0-P7

TABLE A8—F691 TRANSCEIVER PIN NAMES AND DESCRIPTIONS

Pin Number	Pin Name	Description
1	VBAT	positive supply
2	GND	ground
3	BUSP	positive bus output drive
4	BUSN	negative bus output drive
5	RCVP	positive bus receiver input
6	RCVN	negative bus receiver input
7	K	ISO 9141-2 K line, input/output
8	L	ISO 9141-2 L line, output
9	ISO_RX	digital output, ISO 9141-2 receive signal
10	ISO_TX	digital input, ISO 9141-2 transmit signal
11	XMITJ	digital input, SAE J1850 xmit signal
12	RCVJ	digital output, SAE J1850 receive signal
13	CONFIG1	digital input, configuration bit
14	CONFIG2	digital input, configuration bit
15	CONFIG3	digital input, configuration bit
16	FAULT	digital output, fault detection

A.5.5 Additional Capabilities—The following is a list of additional SAE J1850 features supported by the F690 Codec/F691 Transceiver:

a. Checksum and CRC error checking
b. Comprehends IBS
c. Single Byte header support
d. generation of a Break signal

A.6 Motorola ICI and ISO 9141-2 Interface Example—This example (see Figure A7a) combines the use of the SAB J1850 Communications Interface (ICI) developed by Motorola, a discrete 41.6 Kbps transceiver, a discrete 10.4 Kbps transceiver, and the common ISO 9141-2 interface to provide the required interface support. Figure A7b shows the detail of the ICI.

This section contains a description of the ICI interface, which provides all of the required SAE J1850 interface support.

A description of the ISO 9141-2 interface is found in the section titled Common ISO 9141-2 Support.

The ICI communicates with the host through the host's SPI port, while the ISO 9141-2 interface communicates with the host via the host's SCI port. Separate logic interface lines from the host are used to enable either the ICI or the ISO 9141-2 interface.

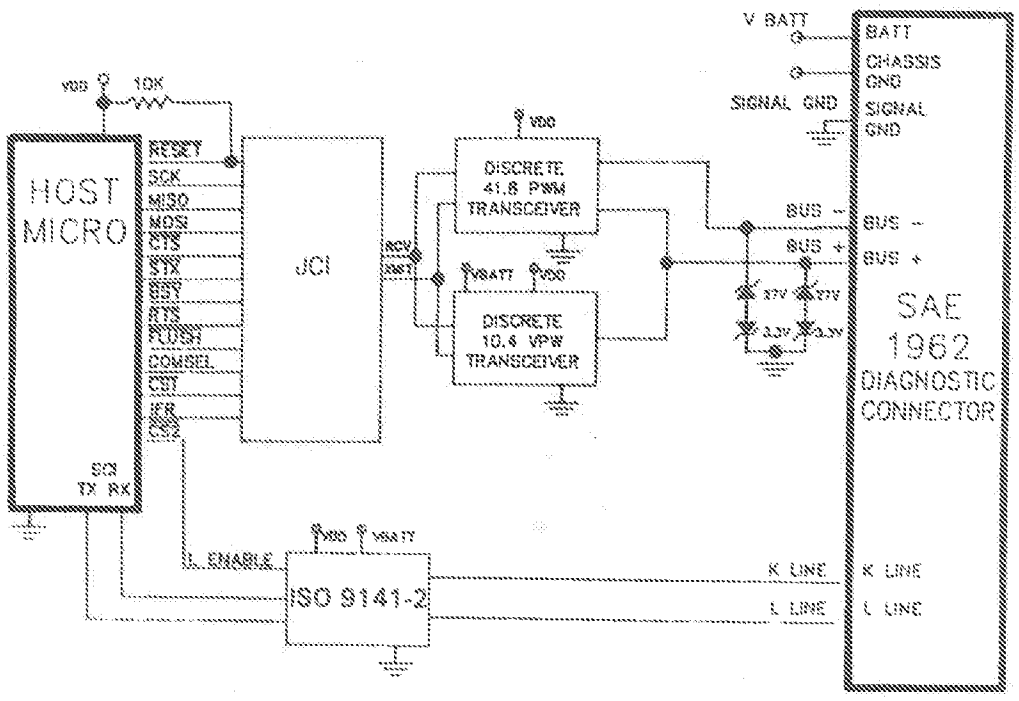


FIGURE A7a—JCI AND ISO 9141-2 EXAMPLE

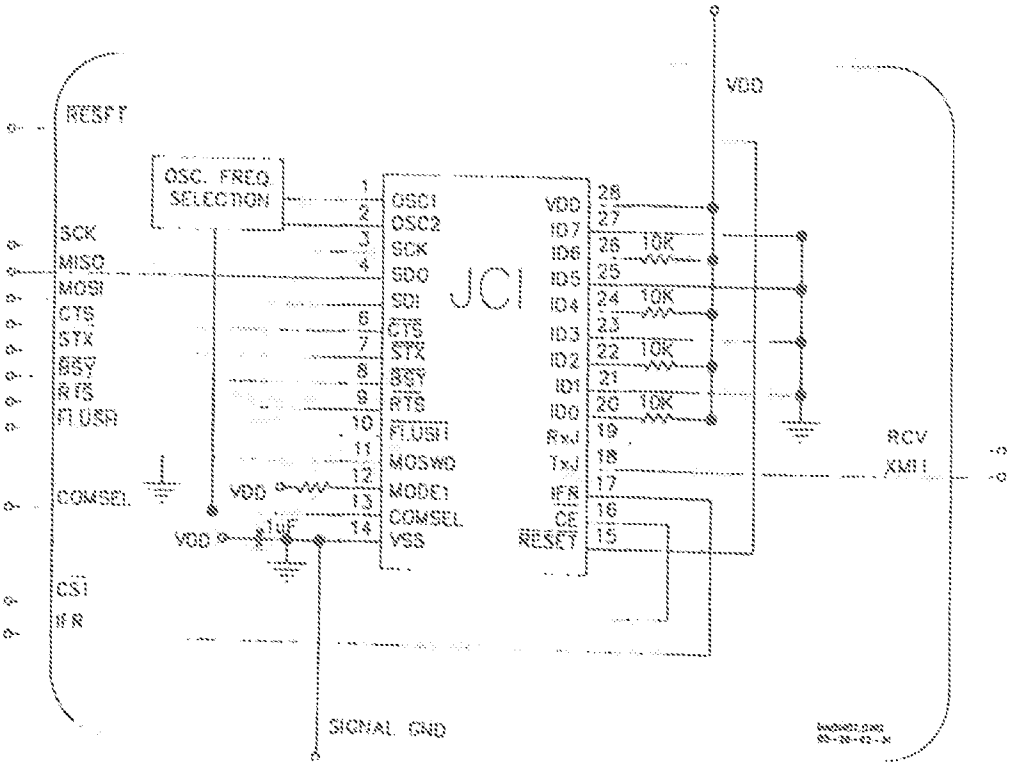


FIGURE A7b—MOTOROLA J1850 COMMUNICATIONS INTERFACE

A.6.1 General Overview—The JCI is an all-digital communications peripheral device which performs all of the required SAE J1850 communications tasks. This reduces the burden on the host to the loading of complete messages into the JCI for transmission onto the multiplex bus, and the unloading of complete messages which the JCI has received from the multiplex bus. The JCI can transmit messages using either modulation technique specified by SAE J1850 (10.4 Kbps VPW and 41.6 Kbps PWM). A separate network transceiver is required to perform all drive, waveshaping, and input compare functions required for proper transmission and reception of each type. This example includes the use of the SGS-Thomson 41.6 Transceiver and 10.4 Transceiver. This example uses several logic lines from the host to enable the JCI interface, and to control the exchange of data between the host and the JCI, while the data exchange occurs via the host's SPI interface port. The ISO 9141-2 interface is as described in A.1.4. The host uses its SCI interface port to communicate with a vehicle through the ISO 9141-2 interface. A logic line is used by the host to enable the L line when necessary.

A.6.2 JCI Operation—The JCI is an all-digital integrated circuit which can support transmission of messages in both modulation formats specified in SAE J1850. The JCI also supports three different types of serial host interfaces, allowing the JCI to be used with a wide range of microcontrollers. This example utilizes the 'Handshake SPI' interface mode. The JCI contains a single transmit buffer, two receive buffers, bit timing and symbol encoding/decoding circuitry, and CRC generation and checking circuitry. All analog transmission functions must be performed by a separate physical interface transceiver circuit. This example uses two discrete transceiver circuits, one for 10.4kbps VPW and one for 41.6 Kbps PWM.

A.6.2.1 Host Interface—The Handshake SPI interface used to communicate with the JCI uses eight signals to control the transfer of information in a serial format between the host and the JCI, three for data transmission, and the rest for data transfer control and error indication. The actual data transfer is in the standard Motorola SPI format. The five control lines include two outputs from the JCI and three inputs to the JCI. The function of these lines are as follows:

a. Output signals from the JCI to the host:
   (1) Request to Send (RTS)—Informs the host that the JCI has data to be transmitted to the host.
   (2) Busy (BSY)—Informs the host that the JCI has a message in its transmit buffer to be transmitted onto the multiplex bus.

b. Input signals to the JCI from the host:
   (1) Chip Enable (CE)—Enables the JCI for communication with the host.
   (2) Clear to Send (CTS)—Enables the JCI to transmit a byte of data to the host.
   (3) Start Transmit (STX)—Informs the JCI that the host has data to be transmitted to the JCI for transmission onto the multiplex bus. There are also other control inputs to the JCI which control the operating mode of the JCI, and allow clearing of either the receive or transmit buffers by the host if necessary.

A.6.2.2 Communication Mode Selection—Since the JCI can transmit messages in either 10.4 Kbps VPW modulation or 41.6 Kbps PWM modulation types, it is necessary for the host to specify to the JCI which modulation type to use. The modulation type is determined through a combination of the input oscillator frequency and the logic level of the Communication Select input (COMSEL). Table A9 outlines the modulation format and transmission rate selection.

TABLE A9—COMMUNICATION MODE SELECTION

Fosc	COMSEL	Baud Rate	Modulation
8 MHz 4 MHz	Logic 1 Logic 0	41.6 Kbps 10.4 Kbps	PWM VPW

The different oscillator frequencies can be supplied to the JCI through a variety of techniques. If the host cannot supply 4 MHz and 8 MHz clock inputs to the JCI, then an oscillator selection must be devised which would allow the switching of the JCI's input oscillator frequency between 4 and 8 MHz, possibly using the logic level of the COMSEL line to determine the input frequency. The COMSEL input is level sensitive, and therefore switching between VPW and PWM can be performed simply by changing the logic level of the COMSEL input and the oscillator frequency. However, resetting the JCI when changing oscillator frequencies will ensure the JCI will begin communicating with the multiplex bus from a known state.

A.6.2.3 In-Frame Response and I.D. Byte—The JCI supports the optional transmission of an In-Frame Response. This option is selected by the logic level of the IFR input. If the IFR pin is at a logic one, a single byte In-Frame Response containing the I.D. byte will be transmitted at the appropriate time during the message frame. The I.D. byte of the JCI is the byte input on the I.D. pins (ID0-ID7). This byte is latched into the JCI upon reset, and should be hardwired in the application. In this example the I.D. byte of the JCI is hardwired to h'55.

A.6.2.4 Message Transmission—The loading of a message for transmission by the JCI is begun by the host asserting the STX input, and then enabling the SPI interface and transferring a complete message (up to 11 bytes) to the JCI through a series of single byte SPI transfers. After the last byte has been transferred to the JCI, the host disables the SPI interface, and negates the STX input. Once the host has begun transmitting a message to the JCI, the JCI will assert the BSY output. This informs the host that the transmit buffer has data to be transmitted in it. The BSY output will stay asserted until the message is successfully transmitted onto the multiplex bus. Once the STX input is negated, the JCI will then attempt to transmit the message onto the multiplex bus. The JCI will handle all bus access functions, including idle bus detection, arbitration, and automatic retry (if necessary).

A.6.2.5 Message Reception—The JCI will receive and buffer complete messages transmitted onto the multiplex bus. Once an entire message has been received with no errors, and the CRC byte verified as correct, the JCI will inform the host that a message is ready for delivery by asserting the RTS output. When the host is ready to receive the message, it enables the SPI interface, and asserts the CTS input. One byte is then transferred to the host, and the host then negates the CTS input to indicate to the JCI that the byte has been received. This is repeated for each byte until the entire message has been transmitted to the host. When transmission of the last byte of the message begins, the JCI will negate the RTS output, informing the host that the last byte is being transmitted. After the last byte has been received by the host, the host negates the CTS input, and then disables the SPI interface. Since the JCI can buffer two complete messages received from the bus, the JCI may already have another message waiting for transmission to the host when one is finished. In this case, the JCI will still negate RTS to indicate the transmission of the last byte of the first message, and then reassert RTS as soon as the last byte of the first message is received by the host. If the host does not service the JCI before both receive buffers are filled, the JCI will then ignore any other messages transmitted onto the multiplex bus until one of the received buffers is emptied by the host.

A.6.3 JCI Pin Names and Descriptions—The names and descriptions of the pins of the JCI are shown in Table A10.

A.6.4 Additional Capabilities—The JCI supports automatic message retransmission after loss of arbitration, or detection of a transmission error. The JCI will attempt to retransmit a message up to two times if an error is detected in the message received. In the case of arbitration loss, the JCI will attempt to retransmit a message indefinitely. The JCI contains a digital filter to remove short noise pulses occurring on the multiplex bus, and can transmit and receive Break symbols, in either PWM or VPW format. The JCI also contains a metal mask optional message filter to reduce the number of messages passed to the host.

TABLE A10—J03 PIN NAMES AND DESCRIPTIONS

Pin Number	Pin Name	Description
1	OSC1	Oscillator 1
2	OSC2	Oscillator 2
3	SCK	SPI Serial Clock
4	SDO	SPI Serial Data Out
5	SDI	SPI Serial Data In
6	CTS	Clear To Send (Active Low)
7	STX	Start Transmit (Active Low)
8	BSY	Busy (Active Low)
9	RTS	Request To Send (Active Low)
10	FLUSH	Flush Message Buffer (Active Low)
11	MODE0	Mode Select 0
12	MODE1	Mode Select 1
13	COMSEL	Communications Select
14	VSS	Ground
15	RESET	Reset (Active Low)
16	CS	Chip Enable (Active Low)
17	IFR	In Frame Response Enable
18	TxJ	Bus Transmit Output
19	RxJ	Bus Receive Input
20	ID0	I.D. Byte - bit 0
21	ID1	I.D. Byte - bit 1
22	ID2	I.D. Byte - bit 2
23	ID3	I.D. Byte - bit 3
24	ID4	I.D. Byte - bit 4
25	ID5	I.D. Byte - bit 5
26	ID6	I.D. Byte - bit 6
27	ID7	I.D. Byte - bit 7
28	VDD	Power Supply

APPENDIX B
SUPPORTING DOCUMENTS

The following is a list of documents that may be useful to the reader for a further understanding of the examples shown in Appendix A:

Ford Hosted Bus Controller Chip User's Guide

Ford Hosted Bus Controller Circuit

Delco Introduction to GM Class 2 Serial Data Bus XDE - 3100

Delco DLCS/P IC User's Guide XDE - 3101

Delco DLCS/P IC Data Sheets XDE - 3102

Silicon Systems, F691 Transceiver Data Sheet - 67F686

SGS-Thomson, ST9 Family Technical Manual - DBST9TMST/1

SGS-Thomson, ST9 Family 8/16 Bit MCU Programming - DBST9PMST/1

SGS-Thomson, ST9XXX Databook - DBST9ST/1

SGS-Thomson, ST9 Brochure - 8RST9/1190

Motorola, MC68HC05C4/C8, Technical Data 8-Bit Microcomputer - AD1991R2

Motorola, M68HC05 Applications Guide - M68HC05AG/AD

EXPANDED DIAGNOSTIC PROTOCOL FOR OBD II SCAN TOOLS---SAE J2205 DEC95

SAE Recommended Practice

Report of the SAE Vehicle E/E System Diagnostic Standards Committee approved June 1994 and revised December 1995. Rationale statement available.

Foreword---Title 13, California Code of Regulations, Section 1968.1 "Malfunction and Diagnostic System Requirements 1994 and Subsequent Model Year Passenger Cars, Light Duty Trucks, and Medium Duty Vehicles With Feedback Control Systems," more commonly known as OBD II, includes the requirement that motor vehicle manufacturers provide information for the diagnosis and service of emissions-related powertrain components using the SAE J1978 OBD II Scan Tool and commonly available non-microprocessor tools (§ 2.1).

In order for motor vehicle manufacturers to use an SAE J1978 OBD II Scan Tool to diagnose and service emissions related powertrain components:

a. Vehicles must support a message protocol compatible with the facilities of the OBD II Scan Tool and capable of accessing the vehicle services required to diagnose and service vehicle emissions related powertrain components and systems
b. The SAE J1978 OBD II Scan Tool must include facilities that allow the scan tool user to enter, edit, select, and transmit messages to a vehicle; identify the messages to be received from the vehicle, and receive them; and describe how to process the data in the received messages, and process them.

The vehicle communication interface used for this purpose is the one used by the vehicle to support SAE J1979 messages.

The messages to be transmitted or received and processed must conform to the requirements defined in SAE J1979, SAE J1850, and ISO 9141-2, with the exception that the message header and data fields may be vehicle specific.

The purpose of the Expanded Diagnostic Protocol is to define the encoding techniques to be used:

a. To describe to the SAE J1978 OBD II Scan Tool the messages to be transmitted to a vehicle and how they are to be transmitted,
b. To describe to the SAE J1978 OBD II Scan Tool the messages to be received and processed by the scan tool, and
c. To describe to the SAE J1978 OBD II Scan Tool how to process the data in the received messages.

TABLE OF CONTENTS

Foreword
1. Scope
2. References
2.1 Applicable Documents
2.1.1 SAE Publications
2.1.2 ISO Publications
2.1.3 Other Publications
2.2 Diagnostic Terms, Definitions, and Acronyms
2.3 Codes Used in This Document
2.4 Tolerance for Timing Values
2.5 User Manual and/or Help Facility
2.6 Significance of Bytes in a Multiple Byte Field of a Received Message
3. Introduction
4. Communication Interfaces and Messages Supported
5. SAE J1978 OBD II Scan Tool EDP Support Requirements
6. EDP Definitions
6.1 Introduction
6.2 Validation of Definition Data
6.3 Id Field
6.3.1 Automatic Execution for Definition Ids 0 to 9
6.4 Definition Length Field
6.5 Definition Type Field
6.6 Transmit Message Field
6.7 Receive Message Filter Field
6.8 Received Data Processing Information (RDPI) Field
6.9 Data Security Verification Field
7 Codes for EDP Definition Fields
7.1 Definition Type Codes
7.1.1 Control Definition Type Codes
7.1.2 Transmit Definition Types
7.1.3 Receive Only Definition Types
7.1.4 Vehicle Manufacturer Reserved Definition Types
7.2 Definition Type Codes Defined
7.3 Received Data Processing Type (RDPT) Codes
7.3.1 Text Display Data in a Definition
7.3.2 Data Conversion
7.3.3 Miscellaneous Display Functions
7.3.4 RDPT Codes for Altering Definition Execution
7.3.5 RDPT Code for Unique Processing of Multiple Received Messages
7.4 Received Data Processing Type Codes Defined
7.4.1 Symbols Used in Describing Received Data Processing Types
7.4.2 Default Data Display Position
7.4.3 Received Data Processing Types With Parameters
7.4.4 Standard Text for Use With Received Data Processing Types
7.4.5 Logic Text Used With Received Data Processing Types
8. Optional Ways of Entering EDP Information
8.1 Use of Bar Codes for Entry of EDP Information
8.2 Other Ways of Entering EDP Information
9. Guidelines for Showing EDP Definitions in Print and by the Scan Tool
APPENDIX A Worked Examples

1. Scope---This SAE Recommended Practice defines the Expanded Diagnostic Protocol (EDP), the requirements for the SAE J1978 OBD II Scan Tool for supporting the EDP protocol, and associated requirements for diagnosis and service information to be provided by motor vehicle manufacturers.

Appendix A includes worked examples of the use of the protocol.

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 J1850---Class B Data Communication Network Interface

SAE J1930---Electrical/Electronic Systems Diagnostic Acronyms, Terms, and Definitions

SAE J1962---Diagnostic Connector

SAE J1978---OBD II Scan Tool

SAE J1979---Common Diagnostic Test Modes

SAE J2008---Recommended Organization of Vehicle Service Information

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

ISO 9141-2:1994(E)---Road vehicles---Diagnostic systems---CARB requirements for interchange of digital information

2.1.3 OTHER PUBLICATIONS

AIAG-B-1 1984---Automotive Industry Action Group---Bar Code Symbology Standard---3 of 9 Bar Code Symbols

Section 1968.1, Title 13, California Code of Regulations, "Malfunction and Diagnostic System Requirements 1994 and Subsequent Model Year Passenger Cars, Light Duty Trucks, and Medium Duty Vehicles With Feedback Control Systems"

Environmental Protection Agency 40 CFR Part 86 Control of Air Pollution From New Motor Vehicles and New Motor Vehicle Engines; Regulations Requiring On-Board Diagnostic Systems on 1994 and Later Model Year Light-Duty Vehicles and Light-Duty Trucks

2.2 Diagnostic Terms, Definitions, and Acronyms---SAE J1930 is hereby referenced as the basis for all such terms in this document, with the following additions:

CRC---Cyclic Redundancy Check---A byte of data appended to message data transmitted on SAE J1850 to ensure detection of corrupted data. CRC is defined in SAE J1850.

DSV---Data Security Verification---A byte of data appended to Extended Diagnostic Protocol definitions to ensure detection of corrupted data in EDP definitions, especially when they are entered and/or edited.

EDP---Extended Diagnostic Protocol---A method of encoding: messages to be transmitted, the selection of messages to be received, and how the data in the received messages are to be processed so that these messages can be processed by the SAE J1978 OBD II Scan Tool.

OBD II—A term commonly used to refer to Section 1968.1, Title 13, California Code of Regulations, "Malfunction and Diagnostic System Requirements 1994 and Subsequent Model Year Passenger Cars, Light Duty Trucks, and Medium Duty Vehicles With Feedback Control Systems."

RDPI—Received Data Processing Information—The information that describes how to process the data in received messages. This information includes a Received Data Processing Type and may include other type specific information.

RDPT—Received Data Processing Type—A code that indicates which data in the received message is to be processed, how the data is encoded, and how it is to be processed.

2.3 Codes Used in This Document—Unless otherwise specified, all codes shown in this document are hexadecimal. All codes shown preceded by a "$" (e.g., $1F) are also hexadecimal.

2.4 Tolerance for Timing Values—Unless otherwise specified, all timing values will have a ±10% tolerance (e.g., 10ms = 10 ms ± 1 ms).

2.5 User Manual and/or Help Facility—References to "user manual" and/or "help facility" in this document refer to the user manual and/or help facility requirement of SAE J1978 OBD II Scan Tool.

2.6 Significance of Bytes in a Multiple Byte Field of a Received Message—With respect to Received Data Processing Type definitions, a multiple byte field in a received message is interpreted first received byte, second received byte, third received byte, etc., and last received byte of the field as the most significant byte, less significant byte(s), and finally, the least significant byte, respectively.

3. Introduction—EDP provides a way of describing to the SAE J1978 OBD II Scan Tool:

a. Messages to be transmitted to the vehicle, and associated operating information (i.e., message repetition rate, etc.),
b. The messages to be received from the vehicle and processed,
c. How to process the data contained in the received messages,
d. Miscellaneous ISO 9141-2 related information (e.g., stop communication message, idle message, when to use the stop message, idle message parameters, etc.).

EDP is intended as an open-ended means for allowing motor vehicle manufacturers to communicate, through the OBD II supported communication interface, with vehicle modules using vehicle and module specific messages. EDP, as a minimum, is available to support diagnosing and servicing emissions-related components and systems.

Motor vehicle manufacturers may include and reference EDP definitions within diagnostic and service procedures for emissions-related components and systems.

4. Communication Interfaces and Messages Supported—The purpose of the functionality defined in this document is to support the use of the SAE J1978 OBD II Scan Tool for communicating with vehicles for the purpose of diagnosing and servicing vehicle emissions-related components and systems. This communication uses messages transmitted to and received from a vehicle that may be unique to a given vehicle manufacturer, model year, vehicle body type, powertrain module, etc. These messages will support facilities unknown at the time this document is developed. Compared to the SAE J1979 messages, these messages may have different message headers and different data fields.

In order to support the communication requirements unique to ISO 9141-2, EDP must support:

a. The user's selection of an address,
b. The transmission of a message that terminates the communication link with the currently addressed module(s), and
c. The definition of an idle message and the characteristics of its transmission.

The other parameters defined by ISO 9141-2 and unmodified by SAE J1978 remain in effect.

EDP messages will use the same vehicle interface that supports the SAE J1979 messages.

Response messages received from an ISO 9141-2 interface must be no longer than 256 bytes.

5. SAE J1978 OBD II Scan Tool EDP Support Requirements—The SAE J1978 OBD II Scan Tool must allow users to enter, edit, and delete EDP definitions, and to select EDP definitions for processing (i.e., execution) and termination.

The SAE J1978 OBD II Scan Tool must be able to repeatedly transmit at least two messages, and monitor for, receive, and process the data in at least four receive message definitions and their associated processing information, simultaneously. A total of at least 256 bytes must be available to retain message bytes received due to active definitions.

The OBD II Scan Tool must allow the entry and retention of a combined total of at least 15 EDP definitions, where each definition may require up to 256 characters. One byte in a definition consists of two characters (e.g., 3C). One field separator (i.e., ",") is one character. One "/" is one character.

The determination of the retention time of EDP definitions after external power is disconnected from the scan tool is left to the discretion of the scan tool manufacturer.

The format of all definitions will include input data security verification (DSV) information and definition length information to minimize data input errors. The scan tool shall indicate to the user the presence of data entry errors in any definition. The scan tool shall allow the user to enter and save definitions that include errors and edit them. The scan tool shall not allow the user to process definitions with errors.

The user's manual/help facility of an SAE J1978 OBD II Scan Tool must document how to enter, edit, delete, select for processing, and select for termination EDP definitions.

The scan tool must support the entry of all the characters used in message definitions, such as hexadecimal data (i.e., 0-9, A-F), a "don't care nibble" identifier character, shown in this document as a "/" (slash), and a field separator character, shown in this document as a "," (comma).

The actual means of performing these actions is left to the scan tool manufacturer. The scan tool user's manual/help facility must describe how to perform these actions.

The processing of EDP definitions shall have no effect on other functions of the SAE J1978 Scan Tool (e.g., automatic determination of OBD II interface, processing of SAE J1979 messages, etc.).

6. EDP Definitions

(R) 6.1 Introduction—There are four general types of EDP definitions:

a. Control type
b. Transmit type
c. Receive only type
d. Miscellaneous type

Each definition type includes a variable set of individual fields (e.g., id field (see 6.3), length field (see 6.4), type field (see 6.5), transmit message information (tx msg) field (see 6.6), receive filter information (rx filter) field (see 6.7), received data processing information (rx data processing info) field (see 6.8), and data security verification information (DSV) field (see 6.9)), each of which are further described in sections below.

The general forms of the four general EDP definition types are:

For control type definitions:
<id>,<length>,<type>,<DSV>
For transmit type definitions:
<id>,<length>,<type>,<tx msg>,<rx filter>,<rx data processing info>,<DSV>
For receive only type definitions:
<id>,<length>,<type>,,<rx filter>,<rx data processing info>,<DSV>
For miscellaneous type definitions:
<id>,<length>,<type and additional information>,<DSV>

6.2 Validation of Definition Data—The SAE J1978 OBD II Scan Tool will check for the correctness of all values entered for a given definition. Correct values for all fields, including the length of the overall definition, the codes used, the lengths of subfields, and the DSV value are required in order for the definition to be allowed to be processed.

6.3 Id Field—The id of a definition is the identification tag that allows a user to select a given definition for editing, deletion, execution, and termination. Some id values (see 6.3.1) imply automatic execution. Id values are assigned by the vehicle manufacturer. Diagnostic and service information shall reference definitions by their id. The id is available for users to indicate definitions to be edited, deleted, executed, and terminated.

The actual method used by a given SAE J1978 OBD II Scan Tool to enable the user to indicate which definition(s) the user wishes the scan tool to process must be described in the scan tool user's manual/help facility.

If a given definition id is already associated with an EDP definition when another message definition using the same id is successfully entered then the previous definition shall be replaced by the new definition.

Relative to vehicle diagnostic or service procedure documentation, where it would be useful, it is recommended that some meaningful identification (i.e., test name - EGR TEST, procedure name - INITIALIZATION, etc.) be associated in vehicle repair procedures with one or a set of definitions that perform an identifiable diagnostic or service procedure. This associated name could be used to directly access effectively similar facilities in scan tools that support them.

Page 678 of 1656 OMEGA EXHIBIT 2037

6.3.1 Automatic Execution for Definition Ids 0 to 9—If a message definition with an id in the range of 0 to 9 is successfully entered into the scan tool then the scan tool shall, in addition to recording this message definition, process it immediately as if it had been entered and selected for processing by the scan tool user. Any currently executing definition having the same definition id shall be terminated and replaced by the new definition.

6.4 Definition Length Field—The length field specifies the length or size of the definition in characters. Definition length is the number of characters in the definition, beginning with the definition id field and ending with the DSV field, inclusive. This includes any "don't care" symbols ("/") and field separators (","). The length field is one byte.

6.5 Definition Type Field—The type field indicates the type of definition.

Control type definitions (see 7.1.1 and 7.2) are used to define general operating parameters such as ones associated with the communication interface. When connected to a given vehicle, the SAE J1978 OBD II Scan Tool will automatically identify the communication interface used by the vehicle for CARB OBD II functions.

Transmit type definitions (see 7.1.2 and 7.2) define messages to be transmitted, how often they are to be transmitted when selected for processing, and optionally, an associated receive message filter and received data processing information.

Receive only type definitions (see 7.1.3 and 7.2) define only a receive message filter and associated received data processing information.

Miscellaneous type definitions are intended to define situations that fall out of the other definition types. Currently there are no miscellaneous definition types.

6.6 Transmit Message Field—The <type> and <tx msg> fields together describe what is to be transmitted and other miscellaneous transmit parameters such as how often the message will be transmitted.

The transmit message field, "<tx msg>", has the form:

aa bb cc ... zz

where:

aa bb cc ... zz are hexadecimal bytes that define the message to be transmitted

The actual message transmitted by the scan tool is determined by the definition type, the interface being used, and the values of aa bb cc ... zz.

If the transmit type is SAE J1979, the transmit message field, "aa bb ... zz", will be interpreted as the SAE J1979 request message mode and mode data. The header for the transmit message and the receive filter information will automatically be as defined by SAE J1979.

As defined in SAE J1850, a CRC will automatically be appended to all messages transmitted on an SAE J1850 interface. As defined in ISO 9141-2, a checksum will automatically be appended to all messages transmitted on an ISO 9141-2 interface.

6.7 Receive Message Filter Field—Receive message filter information, <rx filter>, is used by the scan tool to filter messages for processing from all the messages that may be received by the scan tool from the vehicle.

Specifying receive message filter information is optional but generally is a requirement for effective scan tool usage, particularly for SAE J1850 vehicle interfaces. If no receive message filter information is specified in a transmit or a receive only definition, default receive message filter information may be available in some cases. For example, if the transmit type is SAE J1979, then the associated SAE J1979 response message header definition will be used as the default receive message filter. If the vehicle OBD II interface is ISO 9141-2, then the default receive message filter information will be to use any message received.

Only one definition with a null receive message filter field (i.e., this field does not contain any filter information, such as ",,"), may be active at a time (i.e., all received messages will be processed by the received data processing instructions in this definition). All active non-null receive message filter fields shall take precedence over an active definition with a null receive message filter field. That is, any message detected by the scan tool should be processed against the active non-null received filters first, and processed against an active null receive filter last.

As defined in SAE J1850, a CRC will be expected for all messages received on a SAE J1850 interface. As defined in ISO 9141-2, a checksum will be expected for all messages received on an ISO 9141-2 interface.

The received message filter information has the form:

aa bb cc ... zz

where:

aa bb cc ... zz are nibble (i.e., 4 bits) by nibble indicators of whether to ignore or to match a supplied nibble value:

x = / to ignore a received nibble

= 0 - F to specify the value the received nibble must match

The comparison of received message data with all currently active receive message filters begins with the first byte of the received message and continues for the length of a given receive message filter. The received message must be at least as long as a given filter for that filter to be used. There is no implied meaning given to the data of the received message that are compared with received message filters. A particular vehicle's message protocol may interpret the data compared to received message filters as partial headers, full headers, headers and data, etc.

6.8 Received Data Processing Information (RDPI) Field—Associated with every receive message filter definition is default or specified sets of received data processing information.

Each set of received data processing information defines:

a. Which data in the received message the data processing information applies to
b. How that data is to be interpreted
c. How that data is to be formatted, if displayed
d. Other optional features, such as display constants
e. Other ways in which the data may be processed

If no received data processing information is specified with a given receive message filter, the following default received data processing information will be used:

All data of the received message will be displayed as hexadecimal values, beginning with the first byte of the received message through the last byte of the received message.

The display facilities of a given SAE J1978 OBD II Scan Tool implementation are subdivided into at least two display areas, in keeping with the SAE J1978 OBD II Scan Tool requirement to display simultaneously at least two data values. How a given scan tool actually implements display areas is left to the discretion of the scan tool manufacturer and must be described in the scan tool user's manual/help facility.

More than two display areas may be supported.

If data to be displayed from a given received message is larger than an available display area, the available display area is used as a window, displaying only a portion of the total data to be displayed, beginning with the first character of data to be displayed. The scan tool must allow the user to move the window back and forth over the entire data to be displayed.

The scan tool user's manual/help facility must specify how the display area window is moved back and forth over display data.

The complete set of received data processing information associated with a given received message filter is made up of one or more sets of Receive Data Processing Information <RDPI>:

<rx data processing info> = <RDPI><RDPI> ... <RDPI>

A set of Received Data Processing Instructions <RDPI> is of the form:

<RDPI> = <Received Data Processing Type><additional information>

Received Data Processing Types (RDPT) are further described in 7.3. Any "additional information" depends on the RDPT and is further explained in 7.4.3. The size of each received data processing information is defined by the type and any additional information.

6.9 Data Security Verification Field—The Data Security Verification Field <DSV> field is used with the length field to verify the correct entry of a definition into the scan tool. The value of DSV is the simple 1 byte sum without carry of all byte values in the message definition.

Where a "," is a part of a definition, the ASCII value for "," ($2C) will be included in the DSV calculation in place of the ",". Where an "/x" is a part of a definition, the ASCII value for "/" ($2F) and the value 0x will be included in the DSV calculation in place of the "/x". Where an "x/" is a part of a definition, the ASCII value for "/" ($2F) and the value x0 will be included in the DSV calculation in place of the "x/".

7. Codes for RDP Definition Fields

7.1 Definition Type Codes—The following sections briefly identify the values for Control, Transmit, and Receive Only definition type codes. These codes are more fully explained in 7.2.

7.1.1 CONTROL DEFINITION TYPE CODES—Figure 1 shows the codes defined for Control Type definitions and a short description of the meaning of the codes:

7.1.2 TRANSMIT DEFINITION TYPES—Figure 2 shows the codes defined for Transmit Type definitions and their descriptions:

7.1.3 RECEIVE ONLY DEFINITION TYPES—Figure 3 shows the code defined for Receive Only Type definitions and its description:

7.1.4 VEHICLE MANUFACTURER RESERVED DEFINITION TYPES—Definition type codes $80 - $FF are reserved for use by vehicle manufacturers.

Page 679 of 1656 OMEGA EXHIBIT 2037

Type	Description
12	Terminate the current ISO 9141-2 communication connection and begin the ISO 9141-2 addressing and initialization sequence with the given address
13	Define the idle message to be used for ISO 9141-2 communication
14	Define the stop 9141 communication message to be used to terminate ISO 9141-2 communication
17	Set the standard message retransmission interval
18	Use only two display areas
19	Delete all current definitions
1A	Delete a given definition by id
1B	Deactivate all active receive filters
1C	Deactivate a receive filter by definition id

FIGURE 1—CONTROL DEFINITION TYPE CODES

Type	Description
20	Transmit this message once per selection
21	Transmit this message repeatedly at the standard interval once selected, until selected again, at which time stop the repeated retransmissions
22	Transmit message repeatedly at given interval once selected, until selected again, at which time stop the repeated retransmission
23	Transmit message repeatedly, once selected, at given interval for a given maximum interval, until selected again at which time stop the repeated retransmission
24	Process this message as an SAE J1979 request and transmit once per selection
25	Process this message as an SAE J1979 request and transmit repeatedly at the standard interval once selected, until selected again, at which time stop the repeated retransmission
26	Process this message as an SAE J1979 request and transmit repeatedly at the standard interval once selected, until selected again, at which time stop the repeated retransmission
27	Process this message as an SAE J1979 request and transmit messages repeatedly, once selected, at given interval for a given maximum interval, until selected again at which time stop the repeated retransmission

FIGURE 2—TRANSMIT DEFINITION TYPES

Type	Description
30	Receive only definition

FIGURE 3—RECEIVE ONLY DEFINITION TYPES

7.2 *Definition Type Codes Defined*—For each message definition type, the form of the message type information field, the definition of any additional information, and the processing to be performed by the scan tool is shown.

12 Terminate the current ISO 9141-2 communication connection and begin the ISO 9141-2 addressing and initialization sequence with the given address

12 xx

where: xx = ISO 9141-2 address

When a message definition with this message type is processed by a scan tool and ISO 9141-2 is the OBD II communication interface, the scan tool will terminate the current ISO 9141-2 communication link using a stop 9141 message, if one has been defined, or if one is not defined, will terminate all communication for 5 s to force all active communication to terminate. After active communication has been terminated, a minimum of 300 (decimal) ms of bus idle will be allowed before the scan tool will begin the ISO 9141-2 addressing and initialization process, using the address given in the definition.

It is recommended that the scan tool indicate to the user what is going on whenever a 5 s delay is in progress.

13 Define the idle message to be used for ISO 9141-2 communication

13 aa bb ... zz

where: aa bb ... zz defines the idle message to be used to keep the ISO 9141-2 interface from reverting into address mode

This message definition defines the message to be used to keep the ISO 9141-2 communication link with the currently addressed module active.

14 Define the stop message to be used to terminate ISO 9141-2 communication

14 aa bb ... zz

where: aa bb ... zz defines the message to be used to terminate communication on the ISO 9141-2 interface

Subsequent redefinitions of the stop message replace previous definitions. If no aa bb ... zz data follows the 14, any previously defined stop message is deleted and the stop message facility is not available.

17 Set the standard retransmission interval

17 xx

where: xx becomes the standard retransmission interval, in 10 (decimal) ms increments

When a message definition with this message type is processed by a scan tool, the scan tool will begin to use the value specified for current and subsequent messages that are to be retransmitted at the standard rate.

Until a definition of this type specifies a message retransmission interval, an interval of 120 (decimal) ms shall be used. The retransmission interval is the time between the start of one message transmission and the start of the next transmission of the same message.

18 Use only two display areas

18

When a message definition with this message type is processed by a scan tool, the scan tool will use only two display areas, even if the scan tool is able to support more than two.

19 Delete all current message definitions

19

When this message type is processed by a scan tool, the scan tool will delete all current definitions.

1A Delete a given definition

1A xx

where: xx is a definition id

When this message type is processed by a scan tool, the scan tool will delete the message definition associated with the given id.

1B Deactivate all receive filters

1B

When a message definition with this message type is processed by the scan tool, the scan tool will deactivate all currently active receive message filters.

1C Deactivate a given receive filter

1C xx

where: xx is a definition id

When a message definition with this message type is processed by the scan tool, the scan tool will deactivate the receive filter associated with the given definition id.

20 Transmit given message once

20

When a message definition with this message type is processed by a scan tool, the scan tool will transmit the message contained in this definition, and enable any receive filter information contained in this definition. If the processing of this definition causes the limit of a given scan tool for simultaneously active transmit messages or simultaneously active receive filters to be exceeded, the oldest active transmit message will be terminated or the oldest active receive filter will be deactivated.

21 Transmit given message repeatedly at the standard interval

21

When a message definition with this message type is processed by a scan tool, the scan tool will begin to repeatedly transmit at the standard interval the message defined in this definition. The next time this definition is selected, message retransmission will be terminated. When selected again, the message will again begin to be repeatedly retransmitted, and so on.

The receive filter information associated with the definition selected will be added to the set of simultaneously active receive filters when the transmit message begins to be transmitted and will be deleted from the set of simultaneously active receive filters when message transmission is terminated.

22 Transmit a given message repeatedly at a given interval

22 xx

where: xx is the given interval in 10 (decimal) ms

Same processing as for type 21 except that the retransmission interval is specified in the definition.

23 Transmit a given message repeatedly at a given interval for a given maximum interval

23 xx yy yy

where: xx is the given retransmission interval in 10 (decimal) ms, and yy yy is the maximum transmission interval in seconds

Same processing as for type 22 except that the retransmissions will be terminated at the end of the maximum transmission interval or if this definition is selected again.

24 Process as a SAE J1979 request message and transmit it once per selection

24

When a message definition with this message type is processed by a scan tool, the scan tool will process the message as a SAE J1979 message. The transmit information supplied in this definition begins with the SAE J1979

Page 680 of 1656 OMEGA EXHIBIT 2037

mode value followed by any additional mode specific information. The header for the SAE J1979 message will be according to the OBD II interface type as defined in SAE J1979. The resultant transmit message will be transmitted once per selection. The default receive filter and received data processing information will be as defined for the selected SAE J1979 message.

25 Process this message as an SAE J1979 request and transmit it repeatedly at the standard interval
25

Process the transmit information as is defined for type 24 and transmit this message as is defined for type 21.

26 Process this message as an SAE J1979 request and transmit message repeatedly at given interval
26 xx

where: xx is the given interval in 10 (decimal) ms

Process the transmit information as is defined for type 24 and transmit this message as is defined for type 22.

27 Process this message as an SAE J1979 request and transmit message repeatedly at given interval for a given maximum interval
27 xx yy yy

where: xx is the given retransmission interval in 10 (decimal) ms, and yy yy is the maximum transmission interval in seconds

Process this message as is defined for type 24 and transmit this message as is defined for type 23.

30 Receive only definition

The transmit information field of this definition should be null. Use the receive message filter field of the definition to filter received messages, and process the received messages as defined in the received data processing information field.

7.3 Received Data Processing Type (RDPT) Codes—The following is a list of Received Data Processing Types and a short description of the processing type

7.3.1 TEXT DISPLAY DATA IN A DEFINITION—Text to be displayed as a part of processing of the data from a received message may be defined in a definition. The text may be displayed before and/or after the processed data. RDPTs within the range $00 to $7F are interpreted as standard ASCII codes. Some of these codes are for non-displayable characters (e.g., $0D for carriage return may cause the scan tool to move to the next line or may cause the scan tool to not do anything) and generally should not be used. Character codes for "A" to "Z" and "a" to "z" may be displayed in the same way, if not supported uniquely.

7.3.2 DATA CONVERSION—Figure 4 shows RDPT codes that identify which data in the received message is to be processed, how the data is to be interpreted, and how the data is to be displayed.

RDPT	Description
80	Display byte(s) as hexadecimal
81	Display nibble(s) as hexadecimal
82	Display byte(s) as bits
83	Display byte(s) as bits with display mask
84	Display nibble(s) as bits
85	Display nibble(s) as bits with display mask
86	Display byte(s) as unsigned decimal
87	Display byte(s) as signed decimal
88	Display byte(s) as signed decimal with signed offset
89	Display byte(s) as Y = aX + b, X = signed decimal
8A	Display byte(s) as decimal with binary point
8B	Display byte(s) as DTC if not zero
8C	Display byte(s) as ASCII coded data
8D	Display standard string indexed by byte(s)
8E	Display byte(s) as a percentage with given denominator X = a * (100 (decimal) / denominator)
8F	Display byte(s) with a given signed offset as a percentage with a given denominator X = (N + offset) * (100 (decimal) / denominator)
90	Display byte(s) using given scaling data
91	Display byte(s) as BCD data
92	Display one of indexed text set based on logic value of received data ANDed with given bit mask
93	Display one of indexed text set based on inverse logic; value of received data ANDed with given bit mask

FIGURE 4—DATA CONVERSION

7.3.3 Miscellaneous Display Functions—Figure 5 shows RDPT codes that cause the scan tool to display standard text information, clear parts or all of the display, and control the location of the next information to be displayed

RDPT	Description
9B	Display given standard string
9C	Clear entire display
9A	Clear given display area
9B	Position to beginning of display
9C	Position to beginning of next display area
9D	Position to beginning of given display area
9E	Clear a given display area and position to the beginning of the display area
9F	Display byte(s) as y = aX + b, X = unsigned decimal
B0	Display 0 blanks
B1	Display 1 blanks
B2	Move right 1 position
B3	Move right 2 positions
B4	Move right 4 positions
B5	Move right a given number of positions

FIGURE 5—MISCELLANEOUS DISPLAY FUNCTIONS

7.3.4 RDPT CODES FOR ALTERING DEFINITION EXECUTION—Figure 6 shows RDPT codes that cause the scan tool to alter the execution of definitions based on the data received. They describe what received data is to be processed, what data is to be compared to the received data, what type of data comparison must be found to cause a change in definition execution, and what change to definition execution is to be made if the comparison is true.

RDPT	Description
A0	If byte(s) equal terminate processing of this definition
A1	If byte(s) equal terminate processing of this definition and start processing of a given definition
A2	If byte(s) equal terminate processing of the given definition
A5	If byte(s) not equal terminate processing of this definition
A6	If byte(s) not equal terminate processing of this definition and start processing of a given definition
A8	If byte(s) not equal terminate processing of the given definition

FIGURE 6—RDPT CODES FOR ALTERING DEFINITION EXECUTION

7.3.5 RDPT CODE FOR UNIQUE PROCESSING OF MULTIPLE RECEIVED MESSAGES—Normally, when multiple messages are received due to the same definition, each received message is processed as the latest version of the same message. The last message received is the last one processed and last one displayed. Any previous messages have been processed and replaced by the next received message. In some cases, however, multiple messages received due to the same definition each convey unique information that must be displayed separately. Examples are the response messages to a SAE J1979 mode 3 - Request DTC's message.

Figure 7 shows the RDPT code that causes the scan tool to separately process multiple messages, received due to the same definition, as unique data. The results of the received message processing of each message are to be concatenated, one after another, from the first received message to the last, within the limits of the scan tool to retain all the received data.

When used, this RDPT code must be the first one in a Received Data Processing Information field. When a scan tool cannot retain any more received messages due to a definition that includes this RDPT code, the scan tool shall indicate such an error to the user, and document this error type in the user/help facility. The scan tool will allow the user to scan the processed data as described in SAE J1978 for displaying any data that cannot all be displayed because of the size of the data is greater than the size of the display.

RDPT	Description
C0	Multiple messages received as the result of this definition are to be processed as unique information and displayed, one after the other in the order received, to the limit of the scan tool to retain them. Each selection of the definition that includes this RDPT, or retransmission of any transmit message if included, will restart the collection and processing of received messages.

FIGURE 7—RDPT CODE FOR UNIQUE PROCESSING OF MULTIPLE RECEIVED MESSAGES

7.4 Received Data Processing Type Codes Defined

7.4.1 SYMBOLS USED IN DESCRIBING RECEIVED DATA PROCESSING TYPES—The following defines symbols used in 7.4.3 to describe RDPTs:

xx indicates an offset, in bytes, to the beginning of a data field in the received message (00 = first byte in received message, $01 =

Page 681 of 1656 OMEGA EXHIBIT 2037

second byte in received message, $FF = last byte in received message, $FE = second last byte in received message, etc. Note that the last byte of a received message is the message error detection byte. Some hardware may not make this byte available for processing. If the last message byte is referenced in a RDPT, but is not available, the RDPT will be ignored.)

yy Indicates the length of a data field, in bytes

xy Indicates a combination of an offset, in bytes, to the beginning of a data field and the length of a data field, in bytes, where the "x" and "y" are individual nibbles in one definition byte

where: x = offset, in bytes, to the beginning of a data field in the received message ($0 = first byte in received message, $1 = second byte in received message, $F = 16th (decimal) byte in received message, $E = 15th (decimal) byte in received message, etc.)
y = length of data field, in bytes ($1 = one byte, $2 = two bytes, etc.)
xy = $52 defines a 2 byte data field that begins with the 6th byte of the received message

aa Indicates an offset, in nibbles, to beginning of a data field in the received message ($00 = first nibble in received message, $01 = second nibble, etc.). The first nibble of the message is the most significant nibble of the first byte of the message, the second nibble is the least significant nibble of the first byte of the received message.

bb Indicates the length of a data field, in nibbles ($01 = one nibble, $02 = two nibbles, etc.)

cc ... cc Is a given byte field that is compared with the received data. The length of this field is the same as the received data field, i.e., yy or y. A "f" is used in the given data field to indicate a "don't care" compare of a nibble in the received data field.

dd ... dd Indicates a display mask. The size of the display mask is the same as the size of the data field the mask is to be applied to, i.e., yy or bb. For every bit in the mask whose value is 1, the value of the corresponding bit in the data field is to be displayed. For every bit in the mask whose value is 0, the value of the corresponding bit in the data field is NOT to be displayed. The value of a data bit is displayed as a "1" or a "0".

ee or ee ee Indicates a one or two byte index, typically into a list of string constants ($00 or $0000 is index to first entry, $01 or $0001 is index to second entry, etc.)

ff ... ff Is a bit mask for offset to an indexed standard string. One and only one bit in this bit mask must be a "1".

gg ... gg Is a signed offset value. The length of the signed offset gg ... gg is the same as the received data field, i.e., yy.

7.4.2 DEFAULT DATA DISPLAY POSITION—The description of some received data processing type codes refer to display areas. Unless otherwise specified, the first data to be displayed in a given display area will be displayed at the left most position in the display area. All subsequent data to be displayed will follow this data to the right.

Display areas can be top to bottom, left to right, or both. Unless otherwise specified, the first display area will be the top left one. Subsequent display areas will follow left to right, first on the top line, and then from top to bottom for subsequent lines.

7.4.3 RECEIVED DATA PROCESSING TYPES WITH PARAMETERS—The following show received data processing types with any associated additional information. The following use the symbols shown in 7.4.1.

80 Display byte(s) as hexadecimal
80 xy

81 Display nibble(s) as hexadecimal
81 aa bb

82 Display byte(s) as bits
82 xy

83 Display byte(s) as bits with display mask
83 xy dd ... dd

84 Display nibble(s) as bits
84 aa bb

85 Display nibble(s) as bits with display mask
85 aa bb dd ... dd

86 Display byte(s) as unsigned decimal, with a maximum field size in the received data of 4 bytes
86 xy

87 Display byte(s) as signed decimal data, with a maximum field size in the received data of 4 bytes
87 xy

88 Display byte(s) as signed decimal with signed offset with a maximum field size in the received data of 4 bytes
E = N + offset
where: E = value to be displayed
N = value of field in received message
offset = gg ... gg

89 Display byte(s) as y = aX + b, where X = signed decimal received bytes
89 xy jj kk ... kk
where: jj = one byte signed multiplier (a)
kk = signed offset (b) with same length as data byte(s)

8A Display byte(s) as decimal with binary point, with a maximum field size in the received data of 4 bytes
8A xy pp
where: pp = location of binary point in bits from the right end of the data field, $00 = to the right of the right most bit

8B Display byte(s) as DTC(s) if not zero
8B xy
The data length (y) must be a multiple of the DTC data length (i.e., 2 bytes). A DTC code of 0000 is not displayed.

8C Display byte(s) as ASCII codes
8C xy

8D Display standard text indexed by unsigned message byte
8D xy
The index value in the message must be within range of the standard text table (see 7.4.4). If index value is out of range then the tool shall indicate a "data out of range error" and this error shall be explained in the tool user manual/help facility. The maximum field size of the received data is 1 byte.

8E Display byte(s) as percentage with given denominator, with a maximum field size in the received data of 4 bytes
E = N * (100 (decimal)/denominator)
where: E = value to be displayed
N = value of field in received message
8E xy zz ... zz
where: zz ... zz is the denominator, and has the same length as the data field

8F Display byte(s) with given signed offset as a percentage with given denominator, with a maximum field size in the received data of 4 bytes
E = (N + offset) * (100 (decimal)/denominator)
where: E = value to be displayed
N = value of field in received message
8F xy gg ... gg zz ... zz
where: zz ... zz is the signed decimal denominator, and has the same length as the data field

90 Display byte(s) using given scaling data, with a maximum field size in the received data of 4 bytes
90 xy ss
where: ss is scaling value:
bit 7 = scaling type:
0 = binary scaling
1 = decimal scaling
bit 6 - 0 = signed scaling power
If P = absolute value of bits 6 - 0:
for bits 7,6 = 00 then E = N * 2**p
= 01 then E = N / 2**p
= 10 then E = N * 10**p
= 11 then E = N / 10**p
where: E = value to be displayed
N = value of field in received message

91 Display byte(s) as BCD data. If any of received data is out of range then the tool shall indicate a "data out of range error" and this error shall be explained in the tool user manual/help facility.
91 xy

92 Display one of a set of two indexed logic texts (see 7.4.5). The index "ee" determines which text set in 7.4.5 to use. The selection of which of the two texts of the indexed set to display is based on ANDing the given bit mask "ff" with the received message byte at location "xx".
92 xx ff ee

93 Same as for 92, except that the result of the ANDing is inverted before selecting which text to display (see 7.4.5).

Page 682 of 1656 OMEGA EXHIBIT 2037

93 xx ff ee
98 Display given standard text (see 7.4.4)
98 ee
where: ee = index into standard text table
99 Clear entire display
99
9A Clear given area
9A hh
where: hh = display area id, $00 = top left display area, $01 = next display area
9B Position to beginning of top left display area
9B
9C Position to beginning of next display area
9C
9D Position to beginning of given display area
9D hh
where: hh = display area id, $00 = top left display area, $01 = next display area
9E Clear given display area and position to beginning of the display area
9E hh
where: hh = display area id, $00 = top left display area, $01 = next display area
9F Display byte(s) as y = aX + b, where X = unsigned decimal received byte(s), with a maximum field size in the received data of 4 bytes
9F xy jj kk ... kk
where: jj = one byte signed multiplier (a)
kk = signed offset (b) with same length as data byte(s)
A0 If received byte(s) equal given value then terminate this definition
A0 xy cc ... cc
A1 If received byte(s) equal given value then terminate this definition and start the given definition
A1 xy cc ... cc ww
where: ww = definition id
A2 If received byte(s) equal given value then terminate the given definition
A2 xy cc ... cc ww
where: ww = definition id
A8 If received byte(s) do not equal given value then terminate this definition
A8 xy cc ... cc
A9 If received byte(s) do not equal given value then terminate this definition and start the given definition
A9 xy cc ... cc ww
where: ww = definition id
AA If received byte(s) do not equal given value then terminate the given definition
AA xy cc ... cc ww
where: ww = definition id
B5 Move right given positions
B5 pp
where: pp = number of positions to move
C0 Process multiple received messages uniquely
C0
This RDPT must be the first RDPT in the received data processing information field.

7.4.4 STANDARD TEXT FOR USE WITH RECEIVED DATA PROCESSING TYPES—Figure 8 shows the standard text associated with RDPT's 8D and 98.

Scan tool manufacturers may use alternate text that conveys the same meaning as the standard text, if the alternative text is documented in the user manual/help facility associated with a given scan tool. Abbreviations found in SAE J1930 for the following phases may also be used. Other abbreviations may be used if they are documented in the scan tool user's guide/help facility.

7.4.5 LOGIC TEXT USED WITH RECEIVED DATA PROCESSING TYPES—Figure 9 shows the logic text associated with RDPT's 92 and 93.

Scan tool manufacturers may also use standard abbreviations. Scan tool manufacturers may use alternate text or alternate abbreviations if such are documented in the user manual/help facility associated with a given scan tool.

Each of the following indexed sets consists of two values. Based on the RDPT type, if the resultant logic value after processing the message data and the additional data is "0," then the text shown under the "0" column, for the index value contained in the RDPT, is to be displayed. In a similar way, if the resultant logic value is "1," then the text shown under the "1" column is to be displayed.

Index	Standard Text	Index	Standard Text
01	Degrees Centigrade or Centigrade	02	Degrees Fahrenheit or Fahrenheit
03	% Calculated Load	04	% Fuel
05	% Full Delay	06	% Fuel Extended
07	% Full Off	08	% Full On
09	% Full Up	0A	% Minimum Torque
0B	% Maximum	0C	% Open
0D	% Remaining Life	0E	% Rich
0F	Counts	10	Idle Pascal Absolute
11	Idle Pascal Gauge	12	grams per second
13	Revolutions	14	Revolutions Per Minute
15	Kilometers Per Hour	16	Miles Per Hour
17	Liter	19	kPa
1A	Degrees CW	1B	Degrees CCW
1D	Liters per 100 Km	1E	milliseconds
1F	Volts	20	Hertz
21	seconds	22	minutes
23	hours	24	Diagnostic Trouble Code
25	gallons	26	gallons per minute
27	Amphere	28	Celsius
31	Purge	32	Egr
33	Misfire	34	Fuel
35	Rich	36	Lean
37	Pass	38	Fail
39	Calculated Load Values	3A	Heated Catalyst
3B	Evaporative	3C	Secondary Air
3D	Oxygen Sensor	3E	Oxygen Sensor Heater
3F	Coolant Temperature	40	Ambient Temperature
41	system	42	Short Term Fuel Trim
43	Long Term Fuel Trim	44	Fuel Pressure
45	MAP	46	BARO
47	Spark Advance	48	Intake Air Temperature
49	Absolute Throttle Position	4A	Air Status
4B	Bank	4C	Sensor
4D	OBD Support	4E	Freeze Frame

FIGURE 8—STANDARD TEXT FOR USE WITH RECEIVED DATA PROCESSING TYPES

8. *Optional Ways of Entering EDP Information*—Some form of user input interface, such as a keyboard, must be available to the scan tool user to enter EDP definition information into the scan tool. However, other means may optionally be used to enter EDP definitions.

8.1 *Use of Bar Codes for Entry of EDP Information*—Optionally, the OBD II Scan Tool may also support the use of a bar code for entering EDP information.

Optionally, motor vehicle manufacturer diagnostic and service information may include EDP definitions in bar coded form.

Index	"0"	"1"
00	OFF	ON
01	FALSE	TRUE
02	DISABLE	ENABLE
03	CLOSED	OPEN
04	METRIC	ENGLISH
05	UNLOCK	LOCK
06	UNSECURED	SECURE
07	SPEED DENSITY	MASS AIRFLOW
08	DECREASE	INCREASE
09	DECREMENT	INCREMENT
10	DOWN	UP
11	OUT	IN
12	BACKWARD	FORWARD
13	NOT SUPPORTED	SUPPORTED
14	MINUS	PLUS
15	LEFT	RIGHT
16	DOWNSTREAM	UPSTREAM
17	BACKPRONT	FRONT
18	Open Loop	Closed Loop

FIGURE 9—LOGIC TEXT USED WITH RECEIVED DATA PROCESSING TYPES

Page 683 of 1656 OMEGA EXHIBIT 2037

In both of these cases the bar code type to be used is defined in AIAG-B-1 1984 AUTOMOTIVE INDUSTRY ACTION GROUP—BAR CODE SYMBOLOGY STANDARD—3 OF 9 BAR CODE SYMBOLS.

8.2 *Other Ways of Entering EDP Information*—Optionally, the OBD II Scan Tool may receive EDP information through a RS-232 interface, an allowed vehicle communication interface, or a cartridge.

The RS-232 interface or the vehicle communication interface, including the SAE J1962 connector, may be used to receive EDP information from sources such as a terminal connected to a SAE J2008 data base.

8. *Guidelines for Showing EDP Definitions to Print and by the Scan Tool*—It can be difficult to read EDP definitions, especially long ones, in documents. However, some printing techniques can be used to make it easier for users to read and keep track of their place in a definition.

Printed definitions can be broken down into small groups with spaces, white space, alternating background shading, alternating fonts (e.g., Arial, non-italic), etc. Alternating EDPI fields could have alternating background.

The scan tool could display the fields of a definition with white space, separators, alternating colors, or alternating shading.

White space could, at the discretion on the scan tool manufacturer, be input and displayed as a part of the definition. The white space would not be considered as a part of a definition as far as any checking and processing of a definition was concerned. Any scan tool memory required for support of white space entry and display would be over and above the requirement for non-white space definition data. The scan tool user manual/help facility would describe any such features.

APPENDIX A
WORKED EXAMPLES

A.1 SAE J1979 Messages as SAE J2285 Definitions

Mode 1 PID 00

00,16,24,0100,,8054,17 or 00,16,24,0100,,82A8,6D

Mode 1 PID 01

00,2E,24,0101,,20865198242082612082712082B1,48

Mode 1 PID 03

00,20,24,0103,,8351FP20836115F,56

Mode 1 PID 04 Calculated Load Value

00,1E,24,0104,,208B51FF9803,E8

Mode 1 PID 05 Engine Coolant Temperature

00,20,24,0105,,208851D8209801,DC

Mode 1 PID 06 Short Term Fuel Trim—Bank 1

00,1C,24,0106,,208F51D880,A7

Mode 1 PID 0A Fuel Pressure (gage)

00,1C,24,010A,,2089510300,50

Mode 1 PID 0B Intake Manifold Absolute Pressure

00,18,24,010B,,208651,47

Mode 1 PID 0C Engine RPM

00,18,24,010C,,905202,35

Mode 1 PID 0D Vehicle Speed

00,16,24,010D,,8651,27

Mode 1 PID 0F Intake Air Temperature

00,18,24,010F,,8651D8,05

Mode 1 PID 10 Air Flow Rate—MAF Sensor

00,18,24,0110,,905282,B9

A.2 Expanded SAE J1979 Worked Example

Mode 1 PID 01

00,2E,24,0101,,20865198242082612082712082B1,48

id = 00

The id of this definition is 00. Because the id is in the range of 00 to 09, the scan tool will execute this definition immediately once entered successfully.

length = 2E

The length (52E = 46 decimal) indicates the number of characters in the definition, including the length field and the DSV field. It is checked for entry accuracy.

type = 24

This is an SAE J1979 type definition. The first byte of the given message field will just be the SAE J1979 mode value. The rest of the message will be defined by the mode value. The header for the transmit message is also the interface currently being used. The receive filter is defined by the transmit message header.

transmit field = 0101

This is a mode 01 SAE J1979 request message. A second byte must be defined for mode 01 request messages. The PID value is 01.

Receive filter field = <null>

The receive filter will be the default defined by the definition type and actual transmit message header.

Received data processing field = 20865198242082612082712082B1

20	ASCII code for 1 blank.
8651	Display bytes as unsigned decimal, field starts at byte 1 and is 1 byte in size. Byte 5 of the received response message is SAE J1979 response data byte 3, which is the number of emission related powertrain diagnostic trouble codes.
9824	Display standard text $24. This is "DTC."
20	Same as above.
8261	Display bytes as bits, field starts at byte 6 and is 1 byte in size. Byte 6 of the received response message is SAE J1979 response data byte 4, which is the evaluation/Mil status bits.
20	Same as above.
8271	Same as 8261 above, except this is for SAE J1979 support byte 5, which is evaluation support bits.
20	Same as above.
8281	Same as above, except this is for SAE J1979 response data byte 6, which is the evaluation status bits.

DSV = 48 This is the DSV value for this definition.

OMEGA EXHIBIT 2037

CLASS B DATA COMMUNICATIONS NETWORK INTERFACE—SAE J1850 JUL95

SAE Standard

Report of the SAE Vehicle Network for Multiplexing and Data Communications Standards Committee approved November 1988, completely revised July 1990 and August 1991, and revised May 1994 and July 1995.

Table of Contents

1. Scope
1.1 Objectives
2. References
2.1 Applicable Documents
2.1.1 SAE Publications
2.1.2 CISPR Publication
2.1.3 ISO Publications
2.2 Related Publication
2.2.1 SAE Publication
2.3 Definitions
2.4 Abbreviations/Acronyms
3. Description of the Architecture
3.1 General
3.2 Network Topology
3.2.1 Data Bus Topology
3.2.2 Data Bus Control
3.3 References to the OSI Model
3.3.1 Application Layer
3.3.2 Data Link Layer
3.3.3 Physical Layer
3.4 Network Implementation
4. Application Layer Details
4.1 Normal Vehicle Operation (Down the Road) Messages
4.2 Diagnostic Messages
4.2.1 Diagnostic Parametric Data
4.2.2 Diagnostic Malfunction Codes
4.3 Frame Filtering
5. Data Link Layer Details
5.1 Addressing Strategy
5.1.1 Physical Addressing
5.1.2 Functional Addressing
5.2 Network Access and Data Synchronization
5.2.1 Full Message Buffering
5.2.2 Byte Buffering
5.3 Network Elements and Structure
5.3.1 Frame Elements
5.3.2 Bit Ordering
5.3.3 Maximum Frame Length
5.3.4 Function of SOF, EOD, EOF, IFS, NB, and BRK
5.3.4.1 Start of Frame (SOF)
5.3.4.2 End of Data (EOD)
5.3.4.3 End of Frame (EOF)
5.3.4.4 Inter-Frame Separation (IFS)
5.3.4.5 Normalization Bit (NB)
5.3.4.6 Break (BRK)
5.3.5 Idle Bus (Idle)
5.3.6 Data Byte(s)
5.3.7 In-Frame Response (IFR)
5.3.7.1 Normalization Bit
5.4 Error Detection
5.4.1 Cyclic Redundancy Check (CRC)
5.4.2 Frame/Message Length
5.4.3 Out-of-Range
5.4.4 Concept of Valid/Invalid Bit/Symbol Detection
5.4.4.1 Invalid Bit Detection
5.4.4.2 Invalid Frame Structure Detection
5.5 Error Response
5.5.1 Transmit
5.5.2 Receive
6. Physical Layer Details
6.1 Physical Layer Media
6.1.1 Single Wire
6.1.2 Dual Wires
6.1.3 Routing
6.2 Unit Load Specifications
6.3 Maximum Number of Nodes
6.4 Maximum Network Length
6.4.1 On-Vehicle/Off-Vehicle
6.5 Media Characteristics
6.6 Data Bit/Symbol Definition/Detection
6.6.1 Pulse Width Modulation (PWM)
6.6.1.1 The One "1" and Zero "0" Bits
6.6.1.2 Start of Frame (SOF)
6.6.1.3 End of Data (EOD)
6.6.1.4 End of Frame (EOF)
6.6.1.5 Inter-Frame Separation (IFS)
6.6.1.6 Break (BRK)
6.6.1.7 Idle Bus (Idle)
6.6.1.8 PWM Symbol Timing Requirements
6.6.2 Variable Pulse Width Modulation
6.6.2.1 The One "1" and Zero "0" Bits
6.6.2.2 Start Of Frame (SOF)
6.6.2.3 End Of Data (EOD)
6.6.2.4 End of Frame (EOF)
6.6.2.5 In-Frame Response Byte(s)/Normalization Bit
6.6.2.6 Inter-Frame Separation (IFS)
6.6.2.7 Break (BRK)
6.6.2.8 Idle Bus (Idle)
6.6.2.9 VPW Symbol Timing Requirements
6.7 Contention/Arbitration/Priority
6.7.1 Contention Detection
6.7.2 Bit-by-Bit Arbitration
6.7.3 Arbitration Area
6.7.4 Frame Priority
6.8 Node Wake-Up Via Physical Layer
6.8.1 Network Media
6.8.1.1 Unbiased Network
6.8.1.2 Biased Network
6.8.2 Individual Nodes
6.8.2.1 Unpowered Node
6.8.2.2 Sleeping Node
6.8.2.3 Awake/Operational
6.9 Physical Layer Fault Considerations
6.9.1 Required Fault Tolerant Modes
6.9.2 Optional Fault Tolerant Modes
6.10 EMC Requirements
7. Parameters
7.1 Application Layer
7.2 Data Link Layer
7.2.1 Pulse Width Modulation (PWM) at 41.6 Kbps
7.2.2 Variable Pulse Width (VPW) at 10.4 Kbps
7.3 Physical Layer
7.3.1 General Network Requirements
7.3.2 Pulse Width Modulation (PWM)
7.3.2.1 PWM Timing Requirements
7.3.2.2 PWM DC Parameters
7.3.3 Variable Pulse Width Modulation (VPW)
7.3.3.1 VPW Timing Requirements
7.3.3.2 VPW DC Parameters
APPENDIX A - CHECKLIST OF APPLICATION-SPECIFIC FEATURES
APPENDIX B - I/O EMC TEST PLAN
APPENDIX C - VPW WAVEFORM ANALYSIS
APPENDIX D - PWM WAVEFORM ANALYSIS

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 APR89) to allow the sharing of vehicle parametric information. Also per the definition, this Class B network shall be capable of performing Class A functions.

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 Krissi 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 Publications—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 Dr, Warrendale, PA 15096-0001.

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

3. Definitions

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_{dd} volts for Bus + (PWM and VPW) and V_{ss} volts for Bus - (PWM only). Refer to 7.3.2.3 (PWM DC Parameters) and 7.3.3.2 (VPW DC Parameters) for the values of V_{dd} and V_{ss}. The active state voltage level is determined by the source voltage of the bus physical layer drive circuitry.

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

3.1.3 CLASS A DATA COMMUNICATIONS—A system whereby vehicle wiring is reduced by the transmission and reception of multiple signals over a single 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 locations in conventionally wired vehicle.

3.1.4 CLASS B DATA COMMUNICATIONS—A system whereby data (typically 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.

3.1.5 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 closed loop control and to further reduce vehicle wiring. A Class C network shall also be capable of performing Class A and Class B functions.

3.1.6 DOMINANT BIT—A bit which wins arbitration when competing for a bus. For SAE J1850, a logic "0" is the dominant bit.

3.1.7 DUAL WIRE—Two wires that are routed adjacently throughout a network and can be either a twisted or a parallel pair of wires.

3.1.8 FAULT TOLERANCE—The ability of a system to survive a set number of failures with allowance for possible downgraded performance while maintaining message transmission capability at the specified data rate.

3.1.9 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.

3.1.10 FUNCTIONAL ADDRESSING—Labeling of messages based on the operation code or data content. See 5.1.2 for an example of the typical usage of functional addressing.

3.1.11 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.

3.1.12 PASSIVE STATE—The state of a bus wire which results when all nodes have "turned off" their physical layer circuitry. This is V_{ss} volts for Bus + (PWM and VPW) and V_{dd} volts for Bus - (PWM only). Refer to 7.3.2.3 (PWM DC Parameters) and 7.3.3.2 (VPW DC Parameters) for the values of V_{dd} and V_{ss}. The passive state voltage level is determined by the reference voltage of the bus wire termination resistor(s).

3.1.13 PHYSICAL ADDRESSING—Labeling of messages for the physical location of their source and/or destination(s). See 5.1.1 for an example of a typical usage for physical addressing.

3.1.14 PULSE WIDTH MODULATION (PWM)—A data bit format where the width of a pulse of constant voltage or current determines the value (logic one or zero) of the data transmitted.

3.1.15 RECESSIVE BIT—A bit which loses arbitration when competing for a bus with a dominant bit. For SAE J1850, a logic "1" is the recessive bit.

3.1.16 SLEEP-MODE—Node behavior in a low power consumption and inactive state waiting to be switched on by a frame or other activity. This is distinctly an off-mode where the node is disconnected from the power supply.

3.1.17 VARIABLE PULSE WIDTH (VPW) MODULATION—A method of encoding 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.

3.4 Abbreviations/Acronyms

Page 686 of 1656 OMEGA EXHIBIT 2037

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.

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.

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.

Page 687 of 1656 OMEGA EXHIBIT 2037

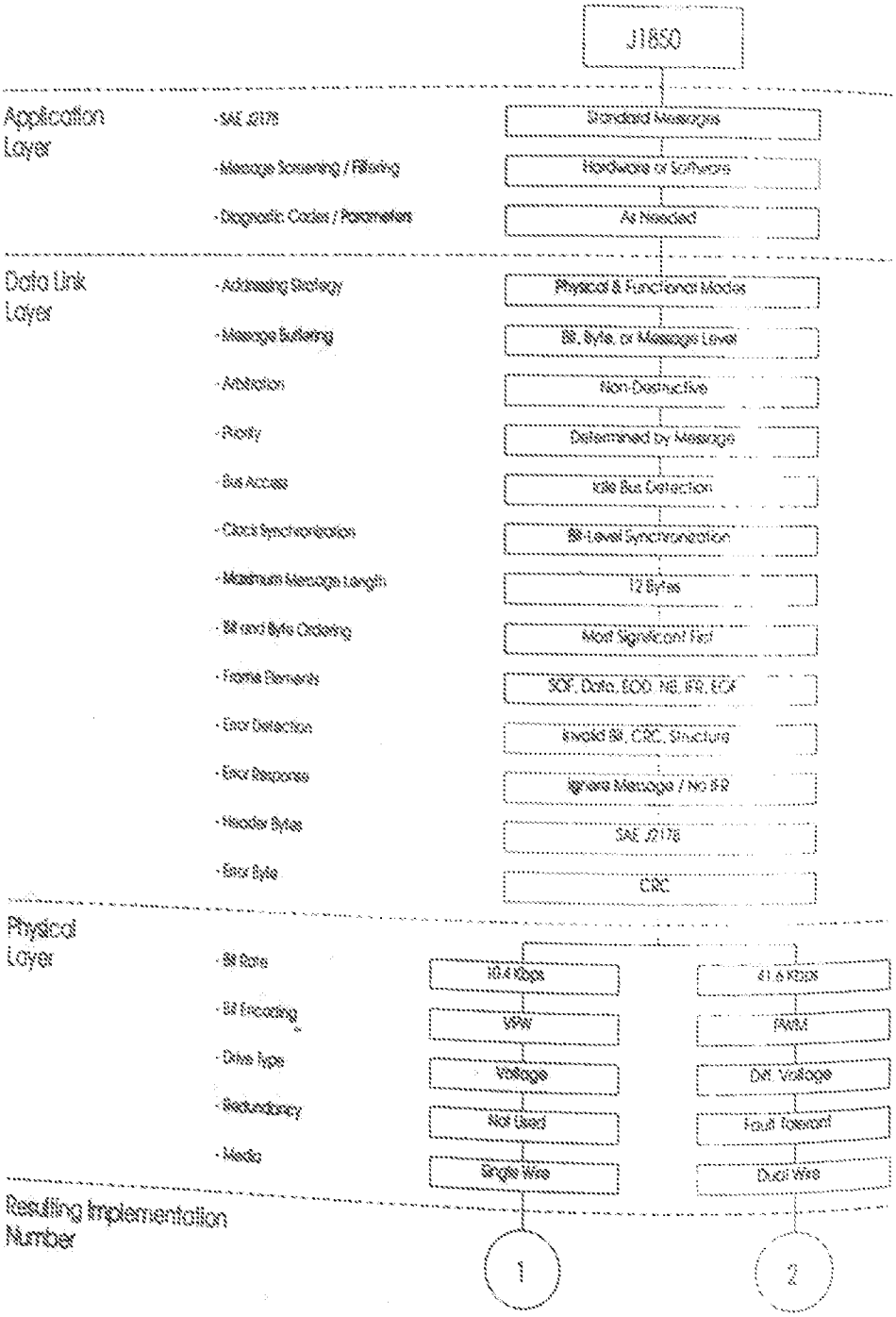


FIGURE 1—MAP OF SAE J1850 TO THE ISO OSI MODEL

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 [illegible] devices based on the function of that frame on the network. Each [illegible] assigned the set of functions that it cares about, either as transmitter [illegible] and can be located anywhere in the network. This type of addressing [illegible] used when the physical location of the function is not important but [illegible] around from one module to another. In the case of functional addressing [illegible] function of the message is important and not the physical addresses of the [illegible]

Single Byte Header:

Bit 7	6	5	4	3	2	1	0
Message ID (2047)							

One Byte Form of Consolidated Header:

Bit 7	6	5	4	3	2	1	0
1	1	1	Rsvd	2	2	2	2
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)			Rsvd	Message Type (see below)			

Bit	Meaning	Value	Meaning
K	In-Frame Response (IFR)	0 1	IFR Required IFR Not Allowed
Y	Addressing Mode	0 1	Functional Addressing Physical Addressing
ZZ	Specific Message Type	0 0 0 1 1 0 1 1	The meaning for these values are dependent on K & Y above. These meanings can be found in J2178/1.

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

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

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.

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 #). 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.

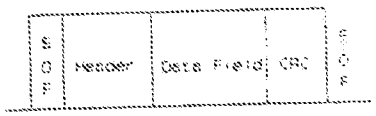
Page 689 of 1656 OMEGA EXHIBIT 2037

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.

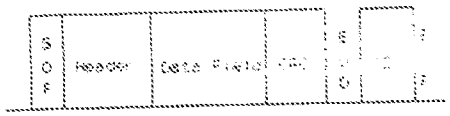
Refer to SAE J2178/1 for a detailed discussion of the different IFR types and for determination of which message types utilize which IFR types.

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.

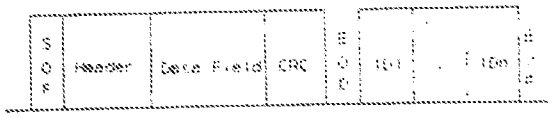
5.3.7.1 Normalization Bit—If the In-Frame Response is employed in the 10.4 Kbps implementation then a "Normalization Bit" is required. The Normalization Bit is described in 6.6.2.5.



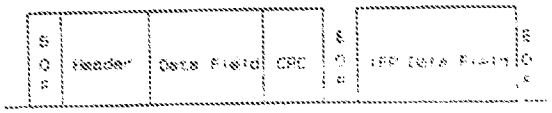
Type 0 - None



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

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:

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

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

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

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

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

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 Byte
00	00	00	00							59
F2	01	83								37
0F	AA	00	55							79
00	FF	55	11							68
33	22	55	AA	BB	CC	DD	EE	FF		C0
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.

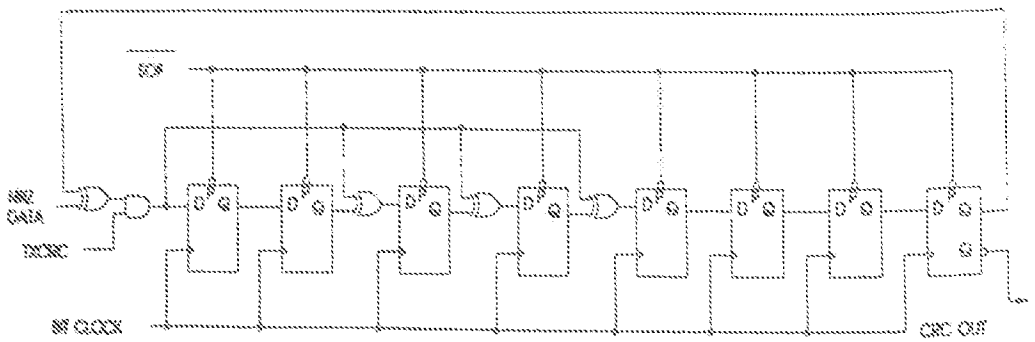


FIGURE 6—CRC GENERATOR

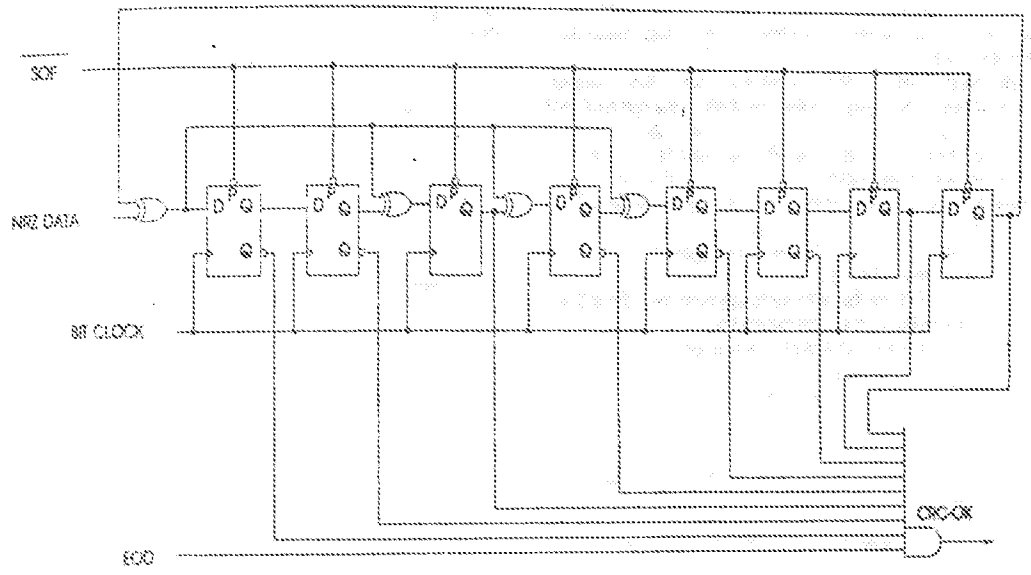


FIGURE 7—CRC CHECKER

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.

5.4.4 CONCEPT OF VALID/INVALID BIT/SYMBOL DETECTION

5.4.4.1 Invalid Bit Detection—In some cases, data integrity may be increased by detecting the condition in the data stream where the received data bit does not match the specifications for either a "one" or a "zero" bit.

5.4.4.2 Invalid Frame Structure Detection—Regardless of data encoding, data integrity may be increased by detecting the condition when an EOD or EOF occurs on a non-byte boundary within the data stream, or the frame exceeds the maximum frame length.

5.5 Error Response

5.5.1 TRANSMIT—When an originator of a frame detects an error condition on the network (i.e., one of the error conditions defined in 5.4), the originator must discontinue the transmit operation prior to the start of the next bit. After the specified period of IFS or reception of an edge after EOF, the originator is allowed to retransmit the frame.

5.5.2 RECEIVE—If a frame is received and the frame contains an error (i.e., one of the error conditions defined in 5.4), the frame is to be ignored. If "In-Frame Response" is being used, the receiver must not respond to a received frame containing an error. This lack of response serves as a signal to the originator that an error was detected by the receiver.

6. *Physical Layer Details*—This section defines the requirements on the following physical layer attributes:

a. Media
b. Unit Load Specifications
c. Maximum Number of Nodes
d. Maximum Network Length
e. Media Characteristics
f. Data Bit/Symbol Definition/Detection
g. Network Wake-Up Via Physical Layer
h. Physical Layer Fault Considerations
i. EMC Requirements

Specific parametric values associated with the physical layer are contained in Section 7.

6.1 Physical Layer Media—Although this specification focuses on the data carrying media, it is assumed that each node shall be supplied with appropriate power and ground.

6.1.1 SINGLE WIRE—The network medium for the single wire voltage drive shall be a single random lay wire.

6.1.2 DUAL WIRES—The network medium for the dual wire voltage drive shall be either a parallel wire pair separated by a constant distance, or a twisted pair of wires.

6.1.3 ROUTING—No Restrictions

6.2 Unit Load Specifications—The electrical loading effect of each device connected to this network will be measured in terms of unit loads. A unit load is a nominal value which, if all nodes correspond to one unit load, will allow the maximum specified number of nodes to be connected to the network. There is no requirement that a given node must be equal to a standard unit load, but the combination of all load values must not exceed the limits for any given system.

6.3 Maximum Number of Nodes—The maximum number of nodes, assuming each node is the equivalent of a standard unit load, is specified in Section 7.

6.4 Maximum Network Length—The maximum medium length between any two nodes shall not exceed the value specified in Section 7.

6.4.1 ON-VEHICLE/OFF-VEHICLE—The maximum network length, maximum capacitance value and minimum load/termination resistance values for any off-vehicle equipment have been specified in 7.3. Because all applications must allow for such off-vehicle equipment, the allowed maximum on-vehicle loads shall be limited to account for this level of off-vehicle loading.

6.5 Media Characteristics—The characteristics of the media are as specified in Section 7.

6.6 Data Bit/Symbol Definition/Detection—The data bus can be in one of two valid states % active or passive. For clarity in the following sections, a rising edge is a transition from the passive to active state and a falling edge is a transition from the active to the passive state.

There are two methods of bit encoding specified in this document, Pulse Width Modulation (PWM) and Variable Pulse Width (VPW) modulation. The timing diagrams that follow represent the requirements for the logical waveform. It is the transmitter's responsibility to transmit bits/symbols which are valid (i.e., it is the transmitter's responsibility to transmit bits/symbols which will meets these specifications). In some contention situations, the transmitter will have to re-synchronize to ensure that the falling edge is within specification. The requirements associated with the reception of these bits and symbols are not stated explicitly in this specification, but are to be derived from transmitter specifications by the module or circuit designer. It is expected that the receiver will employ a simple clock-driven digital filter and digital integrator or majority vote sampling circuit for decoding data and maintaining "clock" synchronization. All timing requirements are specified in Section 7.

The following bits/symbols are defined for both PWM and VPW:

a. One "1" bit
b. Zero "0" bit

c. Start of Frame (SOF)
d. End of Data (EOD)
e. End of Frame (EOF)
f. Inter-Frame Separation (IFS)

The Normalization Bit (NB) is only applicable for VPW implementations and is therefore only defined for VPW.

6.6.1 PULSE WIDTH MODULATION (PWM)—The following values represent nominal timing, detailed timing requirements for each bit/symbol can be found in Section 7.

6.6.1.1 The One "1" and Zero "0" Bits (see Figures 8 and 9)

a. "1" Bit - A "1" bit is characterized by:
   (1) A rising edge that follows the previous rising edge by at least Tp3. Two rising edges shall never be closer than Tp3.
   (2) A falling edge that occurs Tp1 after the rising edge.
b. "0" Bit - A "0" bit is characterized by:
   (1) A rising edge that follows the previous rising edge by at least Tp3. Two rising edges shall never be closer than Tp3.
   (2) A falling edge that occurs Tp2 after the rising edge.
   (3) A next data bit rising edge that occurs Tp11 after the previous falling edge (if applicable).

6.6.1.2 Start of Frame (SOF)—The Start of Frame (SOF) mark has the distinct purpose of uniquely determining the start of a frame (see Figure 10). The SOF is characterized by:

a. A reference rising edge that follows the previous rising edge by at least Tp5.
b. A falling edge that occurs Tp7 after the reference rising edge.
c. The rising edge of the first data bit will occur at Tp10 after the reference rising edge.

NOTE—Last bit of a frame may be the last data bit, last CRC bit, or last In-Frame Response bit.

6.6.1.3 End of Data (EOD)—End of Data 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 immediately after the EOD bit (see Figure 11). If the In-Frame Response feature is not used, then the bus would remain in the passive state for an additional bit time, thereby signifying an End of Frame (EOF).

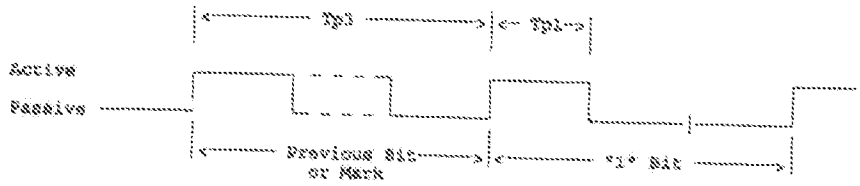


FIGURE 8—"1" BIT DEFINITION

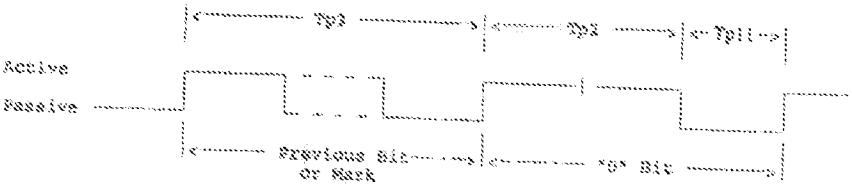


FIGURE 9—"0" BIT DEFINITION

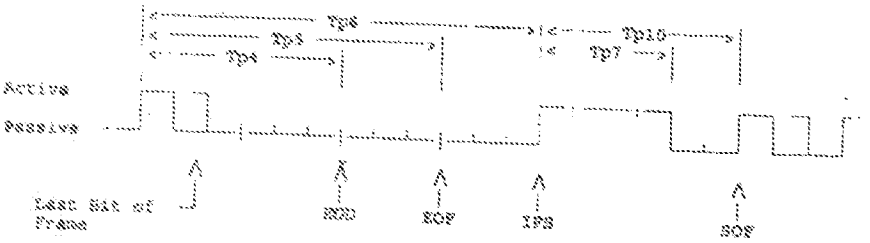


FIGURE 10—FRAME SYMBOLS

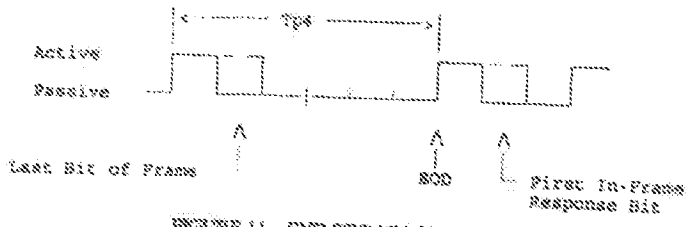


FIGURE 11—END OF DATA SYMBOL

For In-Frame Response, the response byte(s) are driven by the responders and begin with the rising edge of the first bit of the response, Tp4 after the rising edge of the last bit sent from the originator of the frame.

If the first bit of the response byte does not occur at Tp4, and the bus remains passive for one additional bit time (total time Tp5) then the originator and all receivers must consider the frame complete (i.e., EOD has been transformed into an EOF).

NOTE—Last bit of a frame may be the last data bit, last CRC bit, or last In-Frame Response bit.

6.6.1.4 End of Frame (EOF)—The completion of the EOF defines the end of a frame (by definition, an EOD forms the first part of the EOF - see Figure

11). 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 (Tp5 after the rising edge of the last bit), all receivers will consider the transmission complete.

6.6.1.5 Inter-Frame Separation (IFS)—Inter-Frame Separation allows proper synchronization of various nodes during back-to-back frame operation.

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

a. IFS minimum has expired. (Tp6 after the rising edge of the last bit).

b. EOF minimum and another rising edge has been detected. (Tp5 after the rising edge of the last bit).

6.6.1.6 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 (see Figure 12). The PWM Break symbol is an extended SOF symbol and will be detected as an "invalid" symbol to some devices, which will then ignore the current frame, if any. Following the break symbol, an IFS following BRK period (Tp9 after the rising edge of the break) is needed to synchronize the receivers. If the "Breaking" device wishes to obtain guaranteed access to the bus, the highest priority frame must then be sent, otherwise, other frames may gain access under the normal rules of arbitration.

6.6.1.7 Idle Bus (Idle)—Idle bus is defined as any period of passive bus state occurring after IFS minimum (see Figure 13). A node may begin transmission at any time during idle bus.

During an idle bus, any node may transmit immediately. Contention may still occur when two or more nodes transmit nearly simultaneously; therefore, synchronization to rising edges must continue to occur.

NOTE—Last bit of a frame may be the last data bit, last CRC bit, or last In-Frame Response bit.

6.6.1.8 PWM Symbol Timing Requirements—The symbol timing reference for PWM encoding is based on transitions from the passive state to the active state. The SOF and each data bit in PWM has a "leading edge" from which all subsequent timing is derived. The transition from active to passive (which occurs within the SOF or data bits) is not used as a timing reference. The leading edge is used as the only reference because the transition from passive to active appears on the bus wires as a fast clean edge while the transition from active to passive is slow and ambiguous due to variations in network capacitance.

Paragraph 7.3.2.1 defines the timing values for PWM at 41.6 Kbps. Values are provided for the transmitter and receivers (based on the suggested bit decoder implementation).

6.6.2 VARIABLE PULSE WIDTH MODULATION—The SOF symbol, "0" bit, and "1" bit are defined by the time between two consecutive transitions and the level of the bus, active or passive. The EOD, EOF, IFS, and Break symbols are defined simply by the amount of time that has expired since the last transition. EOD, EOF, and IFS are all passive symbols and the Break is an active symbol. Therefore, there is one symbol per transition and one transition per symbol. The end of the previous symbol starts the current symbol. The following values represent nominal timing, detailed timing requirements for each bit/symbol can be found in Section 7.

6.6.2.1 The One "1" and Zero "0" Bits—A "1" bit is either a Tv2 passive pulse or a Tv1 active pulse. Conversely, a "0" bit is either a Tv1 passive pulse or a Tv2 active pulse (see Figure 14). The pulse widths change between passive and active bus states in order to accommodate the arbitration and priority requirements as specified in 6.7.

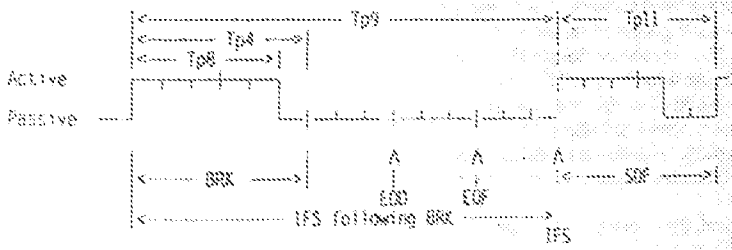


FIGURE 13—PWM BREAK SEQUENCE

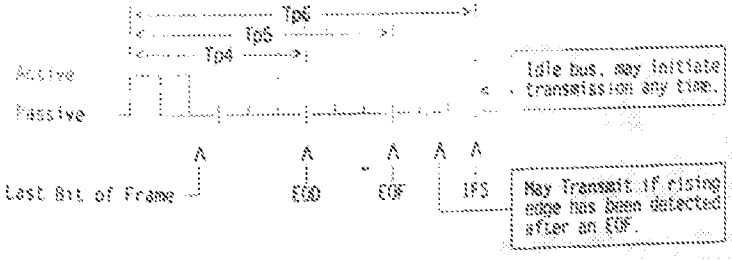


FIGURE 13—SOF AND IDLE BUS DEFINITION

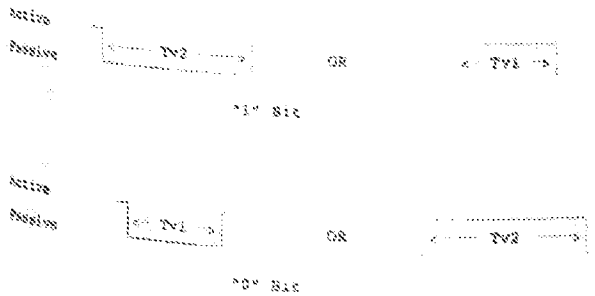


FIGURE 14—ONE AND ZERO BIT DEFINITIONS

6.6.2.2 Start Of Frame (SOF)—SOF is an active pulse, Tv3 in duration (see Figure 15).

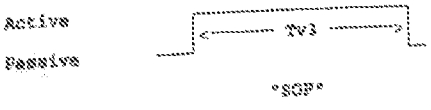


FIGURE 15—START OF FRAME (SOF) SYMBOL

6.6.2.3 End Of Data (EOD)—EOD is a passive pulse, Tv3 in duration (see Figure 16).

OMEGA EXHIBIT 2037

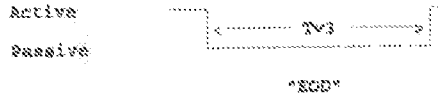


FIGURE 16—END OF DATA (EOD) SYMBOL

6.6.2.4 End of Frame (EOF)—EOF is a passive pulse, Tv4 in duration (see Figure 17).

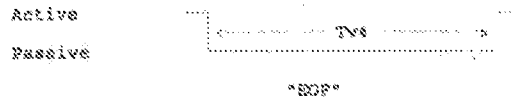


FIGURE 17—END OF FRAME (EOF) SYMBOL

6.6.2.5 In-Frame Response Byte(s)/Normalization Bit—The "In-Frame Response" (IFR) is transmitted by the responder and begins after the passive EOD symbol. For Variable Pulse Width Modulation, the first bit of the IFR data is also passive. Therefore, it is necessary to generate a normalization bit to follow the EOD symbol. The responding device generates the normalization bit prior to sending the IFR data. This normalization bit defines the start of the IFR and can take two forms. The first form is an active short period (Tv1) and the second form is an active long period (Tv2). Figure 18 illustrates the IFR using the normalization bit. The normalization bit can also be used to indicate what type of response is expected during the IFR portion of the frame. The preferred method is to use an active short bit (Tv1) to indicate that the IFR DOES NOT contain a CRC (i.e., IFR types 1 or 2). An active long bit (Tv2) would therefore indicate that the IFR DOES contain a CRC (i.e., IFR type 3). This is only a preferred method, and individual manufacturers are allowed to implement the normalization bit per their requirements. However, all future SAE J1850 applications are urged to implement the normalization bit using the preferred method described above.

If in-frame response bytes are used, the overall frame/message length limit remains in effect. The sum total of data bytes, CRC byte, and in-frame response bytes shall not exceed the value specified in Section 7.

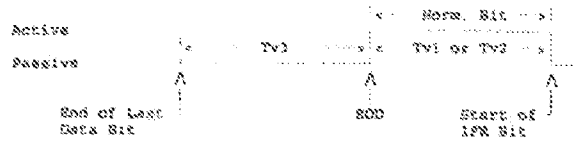


FIGURE 18—NORMALIZATION BIT

6.6.2.6 Inter-Frame Separation (IFS)—Inter-Frame Separation is used to allow proper synchronization of various nodes during back-to-back frame operation.

A transmitter that desires bus access must wait for either of two conditions before transmitting a SOF (see Figure 19):

a. IFS *minimum* has expired (Tv6).

b. EOF minimum and another rising edge has been detected (Tv4).

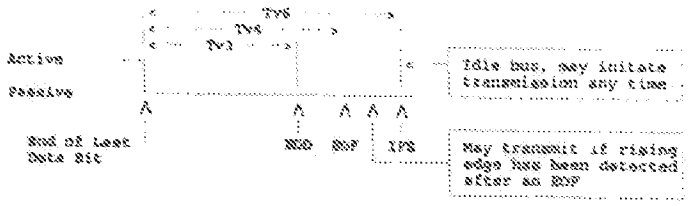


FIGURE 19—INTER-FRAME SEPARATION

6.6.2.7 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 (see Figure 20). The VPW Break symbol will be detected as an "invalid" symbol to some devices, which will then ignore the current frame, if any. The VPW Break symbol is a long active period (Tv5). Following the break symbol, an IFS period (Tv6) is needed to resynchronize the receivers and the normal IFS rules for transmitting a SOF during back-to-back operation apply. If the "Breaking" device wishes to obtain guaranteed access to the bus, the highest priority frame must then be sent, otherwise, other frames may gain access under the normal rules of arbitration.

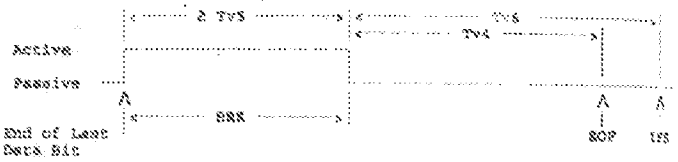


FIGURE 20—BREAK SIGNAL

6.6.2.8 Idle Bus (Idle)—Idle bus is defined as any period of passive bus state occurring after IFS. A node may begin transmission at any time during idle bus.

An idle bus will exist after IFS (Tv6). Contention may still occur when two or more nodes transmit nearly simultaneously; therefore, resynchronization to rising edges must continue to occur.

6.6.2.9 VPW Symbol Timing Requirements—The most important factor in symbol timing uncertainty is the edge position uncertainty due to the time taken to make a transition between $V_{d,max}$ and $V_{th,min}$ (in either direction). The maximum allowable transition time, $T_{t,max}$ (the area between $V_{d,max}$ and $V_{th,min}$), bounds the time span between the earliest and latest node to recognize a transition and is a key design parameter. As $T_{t,max}$ is reduced it becomes more and more difficult to design a driver which also meets the necessary EMI requirements. In this manner, the corners of the waveform, which are a major contributor to the radiated contents of the signal, do not fall within the limits imposed by $T_{t,max}$, as found in Section 7.

Other factors that affect the transmitted pulse width are oscillator tolerance and variations in delay through the receiver, noise filter, and driver. For a fixed oscillator and a well-designed digital filter, most of the variation is in the time it takes the driver to leave the current state and start the transition. The various factors (plus some guard band and allowance for alternative implementations) can be lumped into a single set of limits, $T_{r,min}$ and $T_{r,max}$, for each symbol. Each is measured from the trip point of the previous transition as seen by the transmitting node (assuming a step input) to the beginning or end of the transition at $V_{th,min}$ or $V_{th,max}$.

The pulse width as seen by another node, which may perceive the leading edge either sooner or later than the transmitting node, can range from $T_{x,min} - T_{t,max}$ to $T_{x,max} + T_{t,max}$ in absolute terms. This range represents a receiver's required acceptance range for a given symbol. The actual acceptance range must be wider to allow for receiver oscillator tolerance and any implementation-dependent uncertainties or constraints. The necessary guard band limits how close together symbols can be defined. To keep the symbols short, there is no space allocated for an unambiguous (with normal tolerances) forbidden zone between symbols.

The time windows are not affected by multiple nodes trying to transmit at the same time during arbitration. This is because a single node effectively dominates each transition. It is either the first node to leave the passive state or the last node to leave the active state. Although the fastest or slowest node dominates a particular transition, the contention scheme assures that the highest priority frame always wins regardless of which node started transmitting first.

The purpose of the noise filter is to eliminate impulse noise which may exceed the steady-state noise margin and to minimize the need for hysteresis at the receiver input. The delay through the filter is compensated for in the timing logic. A specific implementation of the filter is not required for compatibility so long as the delay is properly compensated and the uncertainty bounds are not exceeded. In the presence of arbitrary noise during the transition period, the filter should respond as though a single step input had occurred at some point within that period.

The symbol limits defined in Section 7 are consistent with $T_{t,max}$ and the specified oscillator tolerance. T_{nom} is the nominal symbol time with no oscillator error and the receiver detecting the transition at V_t (see analysis in Appendix D).

6.7 Contention/Arbitration/Priority—A contention situation arises when more than one node attempts to access the bus at essentially the same time.

Page 694 of 1656 OMEGA EXHIBIT 2037

6.7.1 CONTENTION DETECTION—Contention detection is the recognition of conflicting symbols or bits. The process of bit-by-bit arbitration allows conflicting frame transmissions to be detected. A node that detects a difference between the symbol or bit it receives and the symbol or bit it is currently transmitting has detected contention to the transmission of its frame. Only the one frame that wins all conflicts of different symbols and bits with all the other nodes that began transmitting during that frame will not detect contention.

6.7.2 BIT-BY-BIT ARBITRATION—The bit-by-bit arbitration scheme described as follows settles the conflicts that occur when multiple nodes attempt to transmit frames simultaneously. This scheme is applied to each symbol/bit of the frame, starting with the SOF symbol and continuing until the end of the frame. Bit-by-bit arbitration is based on the use, at the physical layer, of two values of the bus called the active state and the passive state. All symbols and bits are encoded on the bus by the physical layer as combinations of active and passive state signals. During simultaneous transmissions of active state and passive state signals on the bus, the resultant state on the bus is always active (active state dominates). If the transmitting node detects a signal state on the bus that is different from the state being transmitted by the node during the header portion of the frame, the node must discontinue the transmit operation prior to the start of the next bit. If the transmitting node detects a signal state on the bus that is different from the state being transmitted by the node during the data portion of the frame (following the header), the process used to cease transmission is implementation specific. Some possible options are:

a. Discontinue the transmit operation prior to the start of the next bit (similar to the action taken if contention is detected during the header phase). If transmission of a message is prematurely terminated on a byte boundary due to unexpected contention detection following the header, care must be taken by receiving nodes not to accept the message as a valid one. There is a 1 in 256 chance that the last byte received is the CRC of the previous bytes and would therefore appear to be a valid message. In this case, a node may need to validate the received message to ensure it is of the correct length.

b. Transmit additional bits (< 8) when contention is detected on a byte boundary. This ensures that a framing error will be received by all other receivers in the case of unexpected contention detection possibly due to noise.

Bus access is granted to nodes sending an active state signal over nodes sending a passive state signal. Figure 21 shows this operation on the physical layer, based on the two forms of modulation allowed (PWM and VPW).

The arbitration process begins with the SOF and continues through all the bits of the frames being sent. As each symbol or bit of all the simultaneous frames is transmitted, all of the nodes still transmitting after the last symbol or bit will detect whether any contention is taking place. Nodes that detect contention have, by definition, lost arbitration and will discontinue sending any further symbols or bits. Any remaining nodes will continue to send their symbols/bits until the next contention is detected. The node which obtains sole access to the medium is that which sends its symbols and bits without detecting any contention.

6.7.3 ARBITRATION AREA—The arbitration resolution described previously concerns all the symbols and bits between the SOF and the EOF including, in the case of an in-frame response, all the symbols and bits of the in-frame response. In other words, arbitration acts throughout the frame.

6.7.4 FRAME PRIORITY—The bit-by-bit arbitration mechanism allows the implementation of a frame priority system. When unique frames or, more particularly, when arbitration is resolved down to a single transmitter prior to any data values within the frame, a structure of relative frame priority is inherent.

Should two or more nodes attempt to access the bus within the same frame synchronization window (see IFS in 6.6.1.5 and 6.6.2.7), nondestructive arbitration will occur based on the bit value within each frame. The bus allows two states - active and passive. If an active state bit and a passive state bit are transmitted on the bus simultaneously, then the active state bit will override the passive state bit. Hence, frame arbitration occurs in a bit-wise manner. The result of the arbitration is that the node(s) sending lower priority frame(s) will recognize that they have lost arbitration and will discontinue transmitting before the next bit time. The node transmitting the highest priority frame will continue transmitting uninterrupted.

Based on the bit definitions contained in Section 6.6, the lowest value bytes immediately following the SOF will have the highest priority. Therefore, regardless of the number of bits allocated for "frame prioritization," the numerical value of zero will have the absolutely highest priority (that is, 000 is higher priority than 001 or 111).

6.8 Node Wake-Up Via Physical Layer—The transition to a functional/operating network from an unpowered or standby state is a common occurrence in vehicle multiplex systems. In the context of this document the Session Layer controls the transitions between the operating and the standby states.

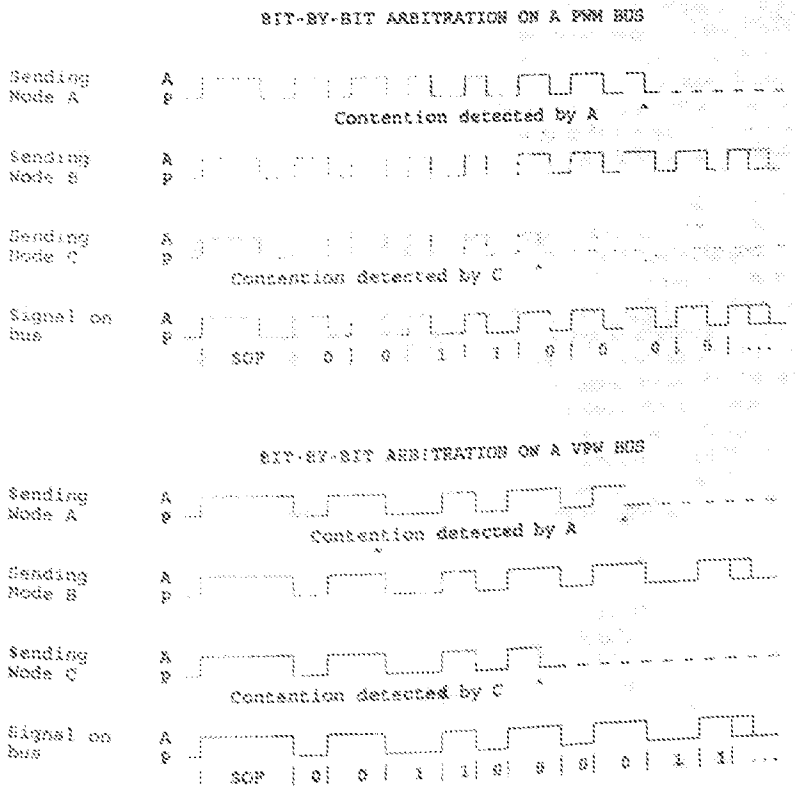


FIGURE 21—ARBITRATION

Two perspectives are used to define the session layer:

a. The view of the media itself, without regard to the individual nodes on the network

b. The view from an individual node

Both are required for a complete definition of the possible states of network operation.

It is expected that a typical vehicle multiplex system may contain a mixture of unpowered and powered nodes, and that the individual nodes may themselves have both powered and standby states.

6.8.1 NETWORK MEDIA

6.8.1.1 Unbiased Network—An unbiased network is all conductors at ground voltage and the impedance of the conductors not controlled. No communication is possible on an unbiased network. The media must first be brought to the biased state before communication can take place. The transition of the network from the unbiased to the biased state may serve as a node wake-up signal for certain applications, but this is not a requirement (i.e., it is possible for individual nodes to be in the sleep state on a fully biased network or in the awake state on an unbiased network).

6.8.1.2 Biased Network—A biased network is all conductors at the "passive" voltage level (with no communication occurring) and with appropriate impedances capable of supporting communication. Individual nodes on the network may exist in any of the three states described as follows. Note that nodes which use the optional sleep state are required to wake up from the appropriate network signal within a defined wake-up period. In other words, all nodes which are capable of wake-up from network signals must do so; otherwise these nodes are considered "unpowered." This requirement assures a finite and limited delay to establish communication with nodes which may be in the sleep state.

The time required for the media to make the transition from the unbiased to the biased state is not defined in this document, since this parameter is largely application dependent and, in fact, may not even occur (e.g., media always biased). For the same reason, the time required for a node to make the transition between the unpowered state and the sleep or awake state is also not defined.

6.8.2 INDIVIDUAL NODES

6.8.2.1 Unpowered Node—An unpowered node is not capable of network communication, nor wake-up from network signal transitions.

6.8.2.2 Sleeping Node—A sleeping node may have an optional low-power standby mode capable of detecting network signal transitions for the purpose of wake-up. Any interface device in the sleep state can be awakened by any other interface device via network activity or awakened by its host via its interface to the host. There is no specified requirement for the transition from the awake state to the sleep state, since this is an implementation-specific issue.

6.8.2.3 Awake/Operational—An awake/operational node is fully capable of receiving and transmitting frames on the network. The maximum amount of time from the wake-up stimulus until the node is capable of communicating is implementation specific. A transition of the bus from the passive state to the active state shall be considered a "wake-up" signal to a sleeping node. Proper bus bias must be supplied by all nodes designated to supply bias when the network is powered.

6.9 Physical Layer Fault Considerations

6.9.1 REQUIRED FAULT TOLERANT MODES—The network must meet the requirements as defined per the following failure modes:

a. Node Power Loss—All nodes must continue to meet the network leakage current requirement during a loss of power (or low voltage) condition.

b. Bus Short to Ground—Network data communications may be interrupted but there shall be no damage to any node when the bus is shorted to ground.

c. Bus Short to Battery—Network data communications may be interrupted but there shall be no damage to any node when the bus is shorted to battery power.

d. Loss of Node Connection to Ground—When a node loses its ground connection, the remaining nodes shall remain capable of communications.

6.9.2 OPTIONAL FAULT TOLERANT MODES—The network may optionally meet the requirements as defined per the following failure modes:

a. Loss of Termination/Bias—Biasing and termination resistors shall be redundant such that no single point failure will cause the network to become inoperative.

b. Loss of Connection to Network—When a node becomes disconnected from the network the remaining nodes shall remain capable of communications.

c. Dual Wire Fault Tolerant Operation—Nodes on a dual wire bus may be capable of full communication (sending and receiving frames) at the specified bit rate in the presence of any one of the following faults occurring anywhere on the network:

(1) Bus "+" wire Open Circuit

(2) Bus "–" wire Open Circuit

(3) Bus "+" wire Shorted to Ground

(4) Bus "–" wire Shorted to Ground

(5) Bus "+" wire Shorted to Battery + (V_{BAT})

(6) Bus "–" wire Shorted to Battery + (V_{BAT})

(7) Bus "+" wire Shorted to any voltage between Ground and Battery

(8) Bus "–" wire Shorted to any voltage between Ground and Battery

Noise immunity and emissions may be somewhat degraded during the fault period but shall return to normal after the fault is removed.

All nodes shall be protected from damage during the presence of these faults such that recovery to normal operation occurs automatically upon removal of fault (i.e., faults shall not propagate through the network).

Continued communication is not required for the "Double Fault" condition of the Bus "+" wire shorted to the Bus "–" wire.

6.10 EMC Requirements—The vehicle manufacturer shall specify the minimum EMC level of operation for a module that utilizes this network interface device. A philosophical method for classification of functional performance can be found in SAE J1113 Part 1 Appendix B (formerly in J1113 Appendix B). A component manufacturer that designs the network device to conform to the most severe classification of Class C (type) is an example, could be assured of adequate performance for all conditions.

The modules that communicate with each other via this network interface shall not generate levels of noise emissions (EMI) large enough to interfere with each other. For reference, the levels defined by CISPR/AWG2 (formerly Sept 1989 may be used. In general, the specifications on wave shape, transition rise and fall times control the EMI levels.

The vehicle manufacturers may find SAE J1211 helpful in qualifying multiplex systems. SAE J1879 may also be utilized for specifying systems.

This document recommends the vehicle manufacturers use the above documents and the outlined EMC test plan defined in Appendix B. EMC voltage "level" requirements specified by the Test Plan are given for reference and the vehicle manufacturer specifications shall be used for compliance tests.

a. Radiated Emissions Antenna & Probe Test (CISPR/AWG2/formerly 19 Sept 1989)

b. Transfer Function, Current probe monitoring (SAE J1113 Part 8)

c. Transfer Function, Antenna monitoring (SAE J1113 Part 8)

d. RF Susceptibility (SAE J1113 Part 13)

e. Transient Susceptibility (SAE J1113 Part 10)

7. Parameters

7.1 Application Layer—The following Application Layer requirements shall exist whenever the network is used.

Bit Dominance - A "0" bit dominates over a "1" bit.

7.2 Data Link Layer

7.2.1 PULSE WIDTH MODULATION (PWM) AT 41.6 Kbps—The nominal frame length from SOF to EOF inclusive is 101 bit times. The nominal number of message bytes (i.e., excluding frame delimiters SOF, EOD, EOF, and IFS) is 12 bytes.

7.2.2 VARIABLE PULSE WIDTH (VPW) AT 10.4 Kbps—The maximum number of message bytes (i.e., excluding frame delimiters SOF, EOD, EOF, and IFS) is 12 bytes.

7.3 Physical Layer

7.3.1 GENERAL NETWORK REQUIREMENTS (see Table 2)

TABLE 2—GENERAL NETWORK PARAMETERS

Parameter Description	Parameter Value
On-Vehicle Network Length	35 meters
Off-Vehicle Network Length	5 meters
Total Vehicle Network Length	40 meters
Maximum number of standard unit loads (including off-vehicle equipment)	32 nodes
Off-vehicle load resistance	10.0 ohms ±5%
Off-vehicle capacitance (each bus wire to signal or chassis ground, as measured at the SAE J1962 connector)	600 pF max

7.3.2 PULSE WIDTH MODULATION (PWM)

7.3.2.1 PWM Timing Requirements—The following requirements for 3, are for a nominal bit time of 24 ms or 41.6 Kbps as seen on the bus media.

Transmit tolerances include oscillator tolerances, physical layer delays (turn-on and turn-off delays), and other miscellaneous tolerances. Receive tolerances include considerations for voltage offsets between transmitter and receiver and other miscellaneous tolerances.

Symbols received in the "gray" areas previously can be decoded as either the symbol before or after that of the "gray" area. For example, an active

Page 696 of 1656 OMEGA EXHIBIT 2037

of 12.5 ms can be decoded as either an active phase "1" (Tp1) or an active phase "0" (Tp2). An incorrect decision will be detected in the CRC error detection byte. Figure 22 gives an example of how a signal should be decoded based on the received pulse width.

TABLE 5—PWM PULSE WIDTH TIMES (MS)

Symbol	Tx,min	Tx,nom	Tx,max	Rx,min	Rx,max
Tp1: Active phase "1"	≥ 7	8	≤ 9	≥ 6	≤ 11
Tp2: Active phase "0"	≥ 15	16	≤ 17	≥ 14	≤ 19
Tp3: Bit time	≥ 23	24	≤ 25.5	≥ 22	≤ 27
Tp4: SOF/EOD time	≥ 67	48	≤ 81	≥ 48	≤ 85
Tp5: EOF time	≥ 70	72	76.5	≥ 70	N/A[1]
Tp6: IFS time	≥ 94	96	N/A[2]	N/A	N/A[2]
Tp7: Active EOF	≥ 35	32	≤ 33	≥ 30	≤ 35
Tp8: Active BRK	≥ 35	40	≤ 41	≥ 38	≤ 45
Tp9: BRK to IFS time	≥ 118	120	N/A[2]	N/A	N/A[2]
Tp10: SOF to Data rising edge	≥ 47	48	≤ 51	≥ 45	≤ 52
Tp11:Passive to next rising edge	≥ 6	N/A	N/A	≥ 4	N/A

[1] EOF transitions into IFS and is not actually a "transmitted" symbol.
[2] Maximum IFS ends at next SOF.

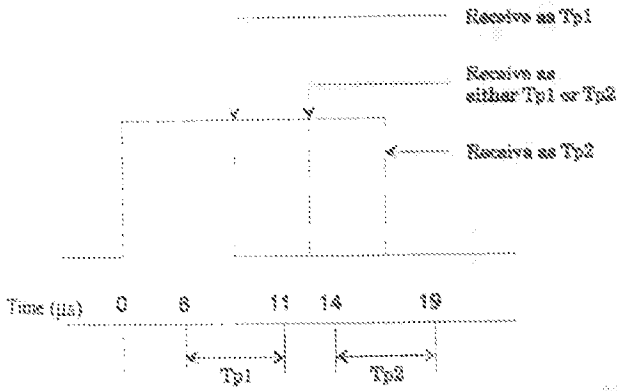


FIGURE 22—EXAMPLE OF RECEIVING A Tp1 OR Tp2 SYMBOL

Note that a pulse width detected between Tp1(min) and Tp1(max) must be decoded as an active phase "1" and a pulse width detected between Tp2(min) and Tp2(max) must be decoded as an active phase "0." However, a pulse width detected between Tp1(max) and Tp2(min) can be decoded as either an active phase "1" or active phase "0."

7.3.2.2 PWM DC Parameters (see Table 8)

7.3.3 VARIABLE PULSE WIDTH MODULATION (VPW)

7.3.3.1 VPW Timing Requirements—The following requirements, Table 9, show the VPW timing values.

7.3.3.2 VPW DC Parameters (see Table 6)

TABLE 8—PWM DC PARAMETERS[1]

Parameter	Symbol	Min	Typ	Max	Units
Input High Voltage	V_{ih}	2.80	--	5.25	V
Input Low Voltage	V_{il}	-1.00	--	2.20	V
Output High Voltage	V_{oh}	3.85	--	5.25	V
Output Low Voltage	V_{ol}	0.00	--	1.00	V
Absolute Ground Offset Voltage	V_{gnd}	0.00	--	1.00	V
Bus (+) Driver & Bus (+) Terminator Supply Voltage	V_{bat}	4.75	5.00	5.25	V
Receiver Input Common Mode Operating Range	V_{cm}	1.60	--	3.75	V
Receiver Hysteresis & Overdrive	V_{hys}	--	--	150	mV
Network Resistance (each wire)	R_{net}	88	--	576	ohms
Network Capacitance (each wire)	C_{net}	300	--	15,000	pF
Network Time Constant[2]	T_{net}	--	--	1.65	µs
Signal Transition Time	T_{trans}	--	--	1.75	µs
Node Resistance (unit load, each wire)	R_{in}	--	5,880	--	ohms
Node Capacitance (unit load, each wire to ground)	C_{in}	--	200	--	pF
Node Capacitance (unit load, wire-to-wire)	C_{in}	--	10	--	pF
Node Leakage Current (each wire - active state)	I_{lkg}	--	--	100	µA
Node Leakage Current (each wire - passive state, unpowered node)	I_{lkg}	--	--	100	µA
Node Leakage Current (each wire - passive state, powered node)	I_{lkg}	--	--	50	µA

[1] Refer to Appendix C for an analysis of the PWM waveform.
[2] The network time constant (T_{net}) is the product of R_{net} and C_{net}. Therefore, some combinations of network resistance and network capacitance are not allowed. The product of R_{net} and C_{net} must always be less than T_{trans}.

TABLE 9—VPW PULSE WIDTH TIMES (MS)

Symbol	Tx,min	Tx,nom	Tx,max	Rx,min	Rx,max
Tv1: Short Pulse	≥ 60	64	≤ 70	> 34	≤ 96
Tv2: Long Pulse	≥ 112	128	≤ 145	> 96	≤ 163
Tv3: SOF/EOD time	≥ 192	200	≤ 218	> 163	≤ 239
Tv4: EOF time	≥ 281	290	N/A[1]	> 239	N/A[1]
Tv5: BRK time	≥ 300	500	≤ 5 ms	> 239	≤ 1.0 s
Tv6: IFS time	≥ 239	300	N/A[2]	> 300	N/A[2]

[1] EOF transitions into IFS and is not actually a "transmitted" symbol.
[2] Maximum IFS ends at next SOF.

TABLE 6—VPW DC PARAMETERS[1]

Parameter	Symbol	Min	Typ	Max	Units
Input High Voltage[2]	V_{ih}	6.25	--	20.00	V
Input Low Voltage	V_{il}	--	--	3.50	V
Output High Voltage	V_{oh}	6.25	--	8.00	V
Output Low Voltage	V_{ol}	0.00	--	1.50	V
Absolute Ground Offset Voltage	V_{gnd}	0.00	--	2.00	V
Network Resistance	R_{net}	815	--	1,875	ohms
Network Capacitance	C_{net}	2,470	--	18,044	pF
Network Time Constant[3]	T_{net}	--	--	8.3	µs
Signal Transition Time	T_{trans}	--	--	18.0	µs
Node Resistance (unit load)	R_{in}	--	10,800	--	ohms
Node Capacitance (unit load)	C_{in}	--	470	--	pF
Node Leakage Current	I_{lkg}	--	--	10	µA

[1] Refer to Appendix C for an analysis of the VPW waveform.
[2] Individual manufacturers may require a higher output level ($V_{oh,min}$).
[3] The network time constant (T_{net}) is the product of R_{net} and C_{net}. Therefore, some combinations of network resistance and network capacitance are not allowed. The product of R_{net} and C_{net} must always be less than T_{trans}.

APPENDIX A
CHECKLIST OF APPLICATION-SPECIFIC FEATURES

A.1 Figure A1 is a checklist provided as an aid to highlight the communication features of J1850.

FEATURES	Tx	Rx	Comments
FRAME ELEMENTS			
General Frame Elements : IFS, SOF, Data, CRC, EOF,			
End of Data (EOD)			
Normalization Bit (NB) - Tv1/Tv2			
BUS ACCESS			
Idle Bus			

Page 697 of 1656 OMEGA EXHIBIT 2037

FEATURES Break (BRK)	Tx	Rx	Comments
N-FRAME RESPONSE			
Type 0 (None)			
Type 1 (Single Byte, Single Responder)			
Type 2 (Single Byte, Multiple Responder)			
Type 3 (Multiple Byte, Single Responder)			
ERROR DETECTION			
Cyclic Redundancy Check (CRC)			
Out of Range			
Invalid Bit			
Invalid Symbol			
Invalid Structure			
Invalid Message Length			
Number of Arbitration Bytes			
FAULT TOLERANCE			
Node Power Loss			
Bus Short to Ground			
Bus Short to Battery			
Loss of Node Ground Connection			
Loss of Termination Resistance			
Loss of Network Connection			
Dual Wire Fault Tolerance			
[illegible] BYTES			
Single Byte			
One Byte Consolidated			
Three Byte Consolidated			
[illegible] ANCE CHECKS			
10.4 KbpsVariable Pulse Width Modulation (VPWM)			
41.6 KbpsPulse Width Modulation (PWM)			
[illegible] ENGTH			
Maximum Frame Size			
Wake-Up Capability			

FIGURE A1 CHECKLIST OF APPLICATION-SPECIFIC FEATURES

APPENDIX B
I/O EMC TEST PLAN

B.1 Radio Disturbance From Vehicle Components—(CISPR/D/WG2 (Secretariat) 19 Sept 1989) - See Figure B1 for diagram.

B.1.1 Radiated Emissions Antenna Test

B.1.1.1 FREQUENCY RANGE—10 kHz to 1.0 GHz

B.1.1.2 BANDWIDTH SETTING

a. Frequency - 10 kHz to 149 kHz, Bandwidth - 1 kHz

b. Frequency - 150 kHz to 1 GHz, Bandwidth - 3 kHz

B.1.1.3 TEST DATA

B.1.1.3.1 Ambient Reference

a. 10 kHz modulation off

b. Both transmitter and receiver power off

c. Sweep signal off

B.1.1.3.2 Idle Bus State

a. 10 kHz modulation off

b. Both transmitter and receiver power on

c. Sweep signal off

B.1.1.3.3 Active Bus State

a. 10 kHz modulation on

b. Both transmitter and receiver power on

c. Sweep signal off

B.1.2 Radiated Emissions Probe Test

B.1.2.1 FREQUENCY RANGE—10 kHz to 200 MHz

B.1.2.2 BANDWIDTH SETTING

a. Frequency - 10 kHz to 149 kHz, Bandwidth - 1 kHz

b. Frequency - 150 kHz to 1 GHz, Bandwidth - 3 kHz

B.1.2.3 PROBE TYPE—As required to make measurements

a. Recommended probe type - Tektronix A6302 (0 - 29 MHz)

b. Recommended probe type - Ailtech 94111-1 (30 - 200 MHz)

B.1.2.4 PROBE DISTANCE—5 cm from part

B.1.2.5 TEST DATA

B.1.2.5.1 Ambient Reference

a. 10 KHz modulation off

b. Both transmitter and receiver power off

c. Sweep signal off

B.1.2.5.2 Idle State

a. 10 kHz modulation off

b. Both transmitter and receiver power on

c. Sweep signal off

B.1.2.5.3 Active Bus

a. 10 kHz modulation on

b. Both transmitter and receiver power on

c. Sweep signal off

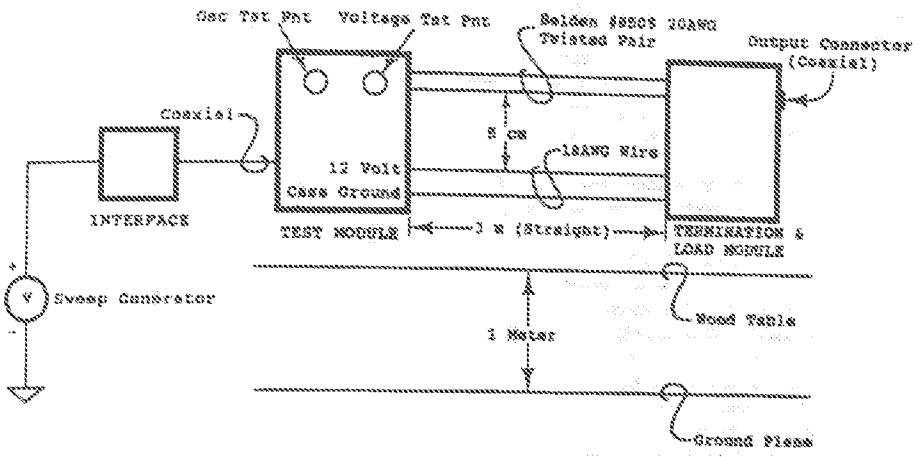


FIGURE B1---EMC TEST SETUP

B.2 Transfer Function---Electromagnetic Susceptibility Measurement Procedures for Vehicle Components

B.2.1 Current Probe Monitoring---Adapted from SAE J1113 Part 2 (Formerly SAE J1113 (Aug 87) Section 2).

a. Frequency - 30 Hz to 250 kHz

b. Amplitude - 1 V peak-to-peak at test point

B.2.2 Antenna Monitoring---Adapted from SAE J1113 Part 3 (Formerly SAE J1113 (Aug 87) Section 3).

a. Frequency: 250 kHz to 200 MHz

b. Attenuator input power: » 25 mW to generate 1 V peak-to-peak at test point

B.2.3 Test Data

B.2.3.1 TRANSFER FUNCTION FROM VCC TO BUS

a. 10 kHz modulation on

b. Both transmitter and receiver power on

c. Sweep signal on

B.2.3.2 TRANSFER FUNCTION FROM GROUND TO BUS

a. 10 kHz modulation on

b. Both transmitter and receiver power on

c. Sweep signal on

B.3 RF Susceptibility---Electromagnetic Susceptibility Measurement Procedures for Common Mode Injection for compliance, test per SAE J1113 Part 13 (formerly SAE J1547).

B.3.1 Frequency Range---1 MHz to 200 MHz.

B.3.2 Max Level---100 mA RMS.

B.3.3 Procedure---Injection and monitoring to be applied to Bus pair only.

B.3.4 Test Data---Record the nature of any interaction occurring below the test level along with the current and frequency.

B.4 Transient Susceptibility---Test per SAE J1113 Part 10 (Adapted from ISO 7637/3).

Test Pulse Amplitude

a. Test Pulse 1: -30 V (Reference)

b. Test Pulse 2: +30 V (Reference)

c. Test Pulse 3a: -60 V (Reference)

d. Test Pulse 3b: +40 Vs (Reference)

APPENDIX C
VPW WAVEFORM ANALYSIS

C.1 VPW Waveform Analysis---Figure C1 shows a drawing of a bus waveform with various voltage levels and trip points. The voltage levels and trip points are defined as follows:

C.2 Voltage Levels and Trip Points

C.2.1 $V_{ch,max}$---Minimum guaranteed output high voltage. This is also the highest trip point, with the source having no ground offset noise, and the receiver having 2 V of noise.

C.2.2 $V_{cl,max}$---Maximum guaranteed output low voltage. This is also the highest trip point, with the receiver having no ground offset noise, and the source having 2 V of noise.

C.2.3 V_r---Ideal receiver trip point.

C.2.4 $V_{ih,min}$---Minimum guaranteed input high voltage and is also the highest trip point with no offset noise.

C.2.5 $V_{il,max}$---Maximum guaranteed input low voltage and is also the lowest trip point with no offset noise.

C.3 VPW Pulse Width Analysis---Factors that affect the transmitted pulse width are oscillator tolerance and variations in delay through the source driver, and the medium. These factors, along with some guard banding, are lumped into a single set of limits called $T_{x,min}$ and $T_{x,max}$ for each bus symbol.

Equations C1 and C2 are used to generate the transmitted pulse values shown in Table C1:

$$T_{x,min} = (T_{nom} - T_{t,max}/2) * 0.98 - T_{x,now} \quad \text{(Eq. C1)}$$

$$T_{x,max} = (T_{nom} + T_{t,max}/2) * 1.02 + T_{x,now} \quad \text{(Eq. C2)}$$

The $(T_{nom} \pm T_{t,max}/2) * 2\%$ factor covers the 2% oscillator tolerance. The T_{nom} and $T_{t,max}$ factors are given in Section 7. The $T_{x,now}$ factor is assumed to be 5.0 which covers the rest of the factors (lumped variation in delay through the source driver and medium).

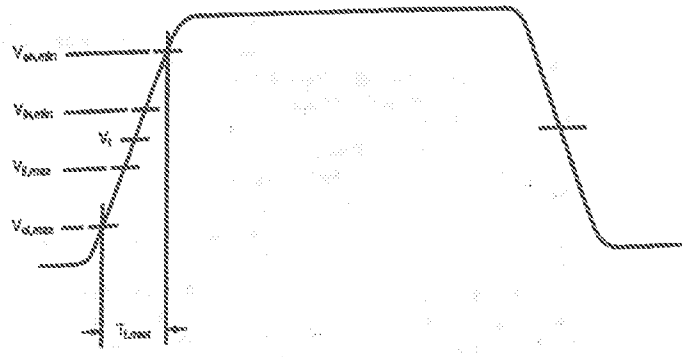


FIGURE C1---VOLTAGE LEVELS AND TRIP POINTS

TABLE C1---VPW PULSE WIDTH TIMES (µs)

Symbol	$T_{x,min}$	$T_{x,nom}$	$T_{x,max}$	$R_{x,min}$	$R_{x,max}$
Tv1: Short Pulse	49	64	79	34	96
Tv2: Long Pulse	112	128	145	96	162
Tv3: SOF/EOD time	182	200	218	164	237
Tv4: EOF time	261	280	N/A	241	N/A

(R) For VPW, node synchronization is an integral part of symbol timing. All transmitting nodes reference their transmit timing from their receiver's perception of the previous edge without regard to whether that edge was due to their own or another transmitter.

Figure C2 shows a plot of T_x, $T_{x,min}$ and $T_{x,max}$. Each is measured from the ideal trip point on the leading edge of the waveform. The fact that what is seen at the source's own receiver contributes to the transmitted pulse width and implies that the source device could be using echoed back information to shape what is transmitted.

(R) The pulse width seen by another node (receiver) can range from $T_{x,min} - T_{r,max}$ to $T_{x,max} + T_{r,max}$. This range comes from the variations in the transmitted pulse width combined with possible noise offset effects on the transmitted and receiving node. The $T_{x,min} - T_{r,max}$ situation occurs when a $T_{x,min}$ pulse width is transmitted by a source node with no ground offset noise, and received by a receiving node with a 2 V of ground offset noise. This sets up the possibility of the receiver tripping at $V_{dr,min}$ on the leading and trailing edge of the waveform. Therefore the pulse width seen by another node for the this $T_{x,min} - T_{r,max}$ situation including the oscillator tolerance and guard banding is given by Equation C4. Equation C5 is derived by including the effect of the real receiver trip point $T_{tp,max}$ in Equation C1 and substituting for $T_{r,max}$ in Equation C4. The $T_{r,max}/2$ factor is equal to zero since an ideal trip point and no ground offset was assumed. The $T_{x,max} + T_{r,max}$ situation occurs with a $T_{x,max}$ pulse being transmitted, the source node having 2V of noise, and the receiver having no offset. This sets up the possibility of the receiving node tripping at $V_{dr,max}$. Again the actual acceptance range must be wider to allow for the receiving node's oscillator tolerance and any implementation-dependent uncertainties or constraints. Similarly Equations C7 and C8 are derived.

The receiving node may perceive the leading edge sooner or later than the transmitting node (source node). This range represents a receiver's required acceptance range for a given bus symbol. Figure C2 shows a drawing of this acceptance range.

The calculations for the received $T_{r,min}$ and $T_{r,max}$ are derived using the factors specified in section 7 for a 2 V ground offset range and a transition rise time of $T_{r,max}$. The transmitting node $T_{r,min}$ factor would be zero (0) if it was a perfect receiver and sensed a transition at the ideal trip point. However, for a real receiver the trip point $T_{tp,max}$ can be approximated by Equation C3 assuming a linear waveform rise time.

(R) $$T_{tp,max} = T_{r,max} * ((V_{tr,max} - V_{dr,max})/(V_{tr,max} - V_{dr,max})) \quad \text{(Eq. C3)}$$

The values for this range shown in Table C1 were arrived at using Equations C6 and C9. Note these values compare favorably with the values specified in Section 7, Table 5.

$$T_{r,min} = (T_{x,min} - T_{r,max}) * 0.98 - T_{r,max} \quad \text{(Eq. C4)}$$

(R) $$T_{r,min} = (((T_{x,min} - T_{tp,max}/2) * 0.98 - T_{r,max}] - T_{r,max}) * 0.98 - T_{r,max} \quad \text{(Eq. C5)}$$

$$T_{r,min} = (((T_{x,min} - T_{tp,max}/2) * 0.98 - T_{r,max}] - T_{r,max}) * 0.98 - T_{r,max} \quad \text{(Eq. C6)}$$

$$T_{r,max} = (T_{r,max} + T_{r,max}) * 1.02 + T_{r,max} \quad \text{(Eq. C7)}$$

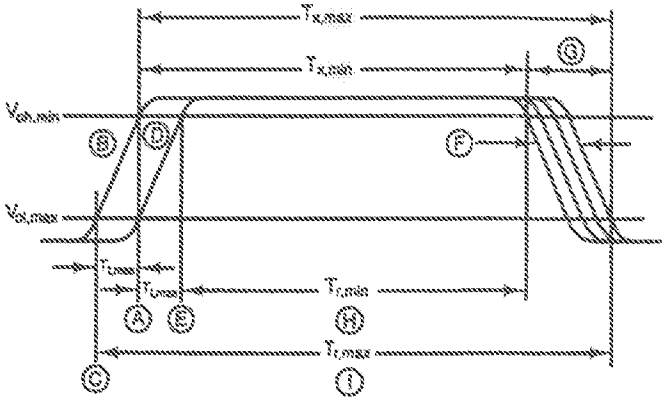
(R) $$T_{r,max} = (((T_{x,max} + T_{tp,max}/2) * 1.02 + T_{r,max}] + T_{r,max}) * 1.02 + T_{r,max} \quad \text{(Eq. C8)}$$

(R) $$T_{r,max} = (((T_{x,max} + T_{tp,max}/2) * 1.02 + T_{r,max}] + T_{r,max}) * 1.02 + T_{r,max} \quad \text{(Eq. C9)}$$

The 2% guard bands cover the oscillator tolerances of both transmitter and receiver and $T_{r,max} = 4.0$ covers the other uncertainties, including receiver delay and digital filter delay. VPW bus symbols allow no forbidden zones between symbols.

Table C1 shows the VPW Pulse Width Timing Requirements

Filter Compensation—The reason for choosing a synchronous data encoding technique is to synchronize at every valid state transition. If the delays through the filter, receiver, and output drivers can be characterized into a constant value, this delay can be compensated for by the timing logic. If variations in delay caused by this Filter and I/O Hardware cannot be easily compensated for, then the Source Interface device variations should be included in the ± 5.0 µs factor defined in $T_{x,min}$ and $T_{x,max}$. All further, variations in delay and including a safety factor for dead zones between symbols for the Receiving device should be included in the ± 4.0 µs factor defined in $T_{r,min}$ and $T_{r,max}$.



A - The trigger point on waveform "B" or "D" where the transmitting node sees the transition ending the previous symbol, and starts timing the current symbol. Take note that a node could trigger at any level of a transition between V_{max} and V_{min}. The maximum and minimum trigger points of any given transition are illustrated by showing the A cutting through two different waveform transitions. This method of illustration allows representing the uncertainties of nodes sensing the beginning and ending of a symbol.

B - The earliest waveform that could trigger the transmitter at point A.

C - The earliest point on waveform "B" that could trigger any other node.

D - The latest waveform that could trigger the transmitter at point A.

E - The latest point on waveform "D" that could trigger any other node.

F - The waveform dispersion due to transmitter tolerances in oscillator, driver, etc.

G - The total transmitter spread when transition time limits are combined with the other tolerances in "F".

H - The shortest legitimate symbol time which can legitimately be seen under worst case conditions.

I - The longest legitimate symbol time which can legitimately be seen under worst case conditions.

NOTES—T_{min} - Starts at V_{min} on waveform "B"; T_{max} - Starts at V_{max} on waveform "D"

FIGURE C2—WAVEFORM TIMING PARAMETERS

APPENDIX D
PWM WAVEFORM ANALYSIS

D.1 PWM Waveform Analysis—Figure D1 shows a drawing of a typical bus waveform with various voltage levels and trip points. Table D1 contains the DC parameter specifications.

D.2 Voltage Levels and Trip Points

D.2.1 V_H—This is the input high voltage which a receiver must detect as an active state on bus (+) and as a passive state on bus (–).

D.2.2 V_L—This is the input low voltage which a transmitter must detect as an active state on bus (–) and as a passive state on bus (+).

D.2.3 V_{oh}—This is the output high voltage which a transmitter must drive bus (+) and the voltage which bus (–) must passively return to. Note that $V_{oh,min}$ is $V_{dr,min}$ plus the absolute maximum ground offset voltage ($V_{gn,max}$).

D.2.4 V_{ol}—This is the output low voltage which a transmitter must drive bus (–) and the voltage which bus (+) must passively return to. Note that $V_{ol,max}$ is $V_{dr,max}$ minus the absolute maximum ground offset voltage ($V_{gn,max}$).

D.2.5 V_{dr}—This is the absolute ground offset voltage that can exist between any two nodes on the network.

D.2.6 V_{dd}—This is the supply voltage which a transmitter must use to drive bus (+) and terminate bus (–)

D.2.7 V_{cm}—This is the receiver input common mode operating range. In order for the differential receiver to recognize a valid signal transition, the bus (+) and bus (–) signals must cross at a voltage within this range.

D.2.8 V_{hys}—This is the receiver hysteresis and overdrive voltage including any power supply reference tolerance.

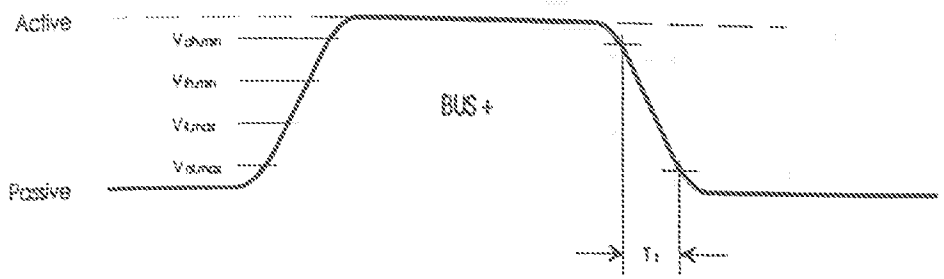
D.2.9 R_{bus}—This is the equivalent network resistance from each bus wire to the corresponding passive voltage source.

D.2.10 C_{bus}—This is the equivalent network capacitance from each bus wire to ground.

D.2.11 T_{bus}—This is the network time constant for each bus wire. This is the product of R_{bus} and C_{bus} of each bus wire. The time constant determines the maximum active-to-passive transition time.

D.2.12 T_r—This is the signal transition time for each bus wire from either the active-to-passive state or passive-to-active state. The passive-to-active edge is driven by the transmitter and shall be no more than $T_{r,max}$. The active-to-passive edge is determined by the network time constant, bus voltage levels, and the passive state supply voltage level.

Page 700 of 1656 OMEGA EXHIBIT 2037



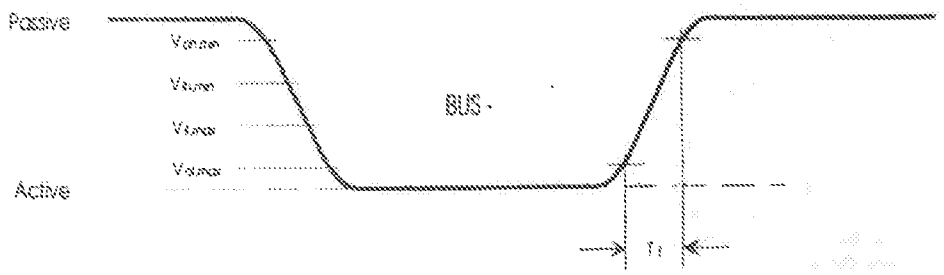


FIGURE D1—TYPICAL PWM WAVEFORM

TABLE D1—PWM DC PARAMETERS

Parameter	Symbol	Min	Typ	Max	Units
Bus High Voltage	V_{+}	2.80	---	5.25	V
Bus Low Voltage	V_{-}	-1.00	---	2.20	V
Output High Voltage	V_{+}	3.80	---	5.25	V
Output Low Voltage	V_{-}	0.00	---	1.20	V
Allowable Ground Offset Voltage	V_{os}	0.00	---	1.00	V
Bus (+) Driver & Bus (-) Termination Supply Voltage	V_{sup}	4.75	5.00	5.25	V
Receiver Input Common Mode Operating Range	V_{cm}	1.80	---	2.75	V
Receiver Hysteresis & Overdrive Voltage	V_{hys}	---	---	180	mV
Network Resistance (each wire)	R_{net}	85	---	378	ohms
Network Capacitance (each wire)	C_{net}	500	---	15,000	pF
Network Time Constant [1]	T_{net}	---	---	1.65	µs
Signal Transition Time	T_t	---	---	1.75	µs
Node Resistance (one load, each wire)	R_n	---	2,880	---	ohms
Node Capacitance (one load, each wire to ground)	C_{ng}	---	250	---	pF
Node Capacitance (one load, wire-to-wire)	C_{nw}	---	10	---	pF
Node Leakage Current (each wire - active state)	I_{nact}	---	---	150	µA
Node Leakage Current (each wire - passive state, unpowered node)	I_{nunp}	---	---	100	µA
Node Leakage Current (each wire - passive state, powered node)	I_{npwr}	---	---	80	µA

[1] The network time constant (T_{net}) is the product of R_{net} and C_{net}. Therefore, some combinations of network resistance and network capacitance are not allowed. The product of R_{net} and C_{net} must always be less than T_t.

D.2.13 C_{ng}—This is the unit load node capacitance of each wire to ground. This capacitance, along with the unit load node capacitance wire-to-wire, results in the total network capacitance referred to in C.2.10.

D.2.14 C_{nw}—This is the unit load node capacitance wire-to-wire. This capacitance along with the node capacitance of each wire to ground results in the total network capacitance referred to in C.2.10.

D.2.15 I_{nact}—This is the leakage current of each wire when the bus is in the active state.

D.2.16 I_{nunp}—This is the leakage current of each wire when the bus is in the passive state and the node is unpowered.

D.2.17 I_{npwr}—This is the leakage current of each wire when the bus is in the passive state and the node is powered.

D.3 Input Voltage Limits—Given the Bus (+) Driver & Bus (–) Termination Supply Voltage (V_{sup}) and the maximum Receiver Hysteresis & Overdrive Voltage (V_{hys}), V_{il} and V_{ih} can be derived. (See Equations D1 through D4.)

$$V_{il,min} = (\text{Ground Reference}) - V_{os} = 0.00 - 1.00 = -1.00\ V \quad \text{(Eq. D1)}$$

$$V_{il,max} = ½ (V_{sup,min}) - V_{hys,max} = ½ (4.75) - 0.18 = 2.20\ V \quad \text{(Eq. D2)}$$

$$V_{ih,min} = ½ (V_{sup,max}) + V_{hys,max} = ½ (5.25) + 0.18 = 2.81\ V \quad \text{(Eq. D3)}$$

$$V_{ih,max} = V_{sup,max} + V_{os} = 5.25 + 1.00 = 6.25\ V \quad \text{(Eq. D4)}$$

where the ½ factor in $V_{il,max}$ and $V_{ih,min}$ assumes a receive comparator voltage level of one-half of the supply voltage. It turns out this is a good tradeoff for voltage ground offset capability versus output drive requirements.

D.4 Output Voltage Limits—Output voltage limits can be derived directly from the input voltage limits. (See Equations D5 through D8.)

$$V_{ol,min} = V_{il,min} + V_{os} = -1.00 + 1.00 = 0\ V\ (\text{Ground Reference}) \quad \text{(Eq. D5)}$$

$$V_{ol,max} = V_{il,max} - V_{os} = 2.20 - 1.00 = 1.20\ V \quad \text{(Eq. D6)}$$

$$V_{oh,min} = V_{ih,min} + V_{os} = 2.80 + 1.00 = 3.80\ V \quad \text{(Eq. D7)}$$

$$V_{oh,max} = V_{ih,max} - V_{os} = 6.25 - 1.00 = 5.25\ (V_{sup,max}) \quad \text{(Eq. D8)}$$

D.5 Network Time Constant & Signal Transition Time—In order to guarantee signal cross over in the Receiver Input Common Mode Operating Range (V_{cm}) the signal transition time must be less than 2.20 µs. This is $T_{t,max}$ + the worst case transition time from $V_{ol,max}$ to $V_{il,max}$ for Bus (–), or $V_{oh,min}$ to $V_{ih,min}$ for Bus (+). Therefore, given $\Delta t = 2.20$ µs, the following relationship for $V_{ol,min}$ must be satisfied for Bus (–) and $V_{oh,max}$ for Bus (+). (See Equations D9 through D12.)

$$V_{ol,min} = V_{sup,min}\,(1 - e^{-\Delta t/T_{net,max}}) \text{ for Bus (–)} \quad \text{(Eq. D9)}$$

$$V_{oh,max} = V_{sup,max}\,(e^{-\Delta t/T_{net,max}}) \text{ for Bus (+)} \quad \text{(Eq. D10)}$$

From this, the maximum network time constant ($T_{net,max}$) can be derived.

$$T_{net,max}(\text{Bus}-) = -\Delta t \div \ln(1-(V_{ol,min}/V_{sup,min})) \quad \text{(Eq. D11)}$$

$$= -0.25 + \log(1 - 3.8654.75)) = 1.37\ \text{ms} \qquad \text{(Eq. D12)}$$

$$T_{Network}(Bus\ e) = -bit\ V_{Level}\ V_{Level})$$

$$= -2.20 + \ln(1.3865.25) = 1.49\ \text{ms}$$

Choosing a $T_{Network}$ of 1.35 μs satisfies both equations. Given a minimum network bias constant of 1.35 μs, the signal transition time T_{Trans} can be found by subtracting the time from V_{Low} to V_{Mid} (for Bus +) or the time from V_{Mid} to V_{Low} (for Bus +) from 2.85 μs. (See Equations D13 through D16.)

Bus (+):

$$T(V_{Low}\ to\ V_{Level}) = -T_{Network}\ (bit(V_{Level}/V_{Level})) \qquad \text{(Eq. D13)}$$

$$= -1.35\ (\ln(1 - 43.2065.75))) = 0.59\ \mu s$$

$$T_{Network} = 2.20 - T(V_{Low}\ to\ V_{Level}) \qquad \text{(Eq. D14)}$$

$$= 2.20 - 0.59 = 1.81\ \mu s$$

Bus (-):

$$T(V_{Low}\ to\ V_{Level}) = -T_{Network}\ (bit(V_{Level}/V_{Level})) \qquad \text{(Eq. D15)}$$

$$= -1.35\ (\ln(3.3865.25))) = 0.44\ \mu s$$

$$T_{Network} = 2.20 - T(V_{Low}\ to\ V_{Level}) \qquad \text{(Eq. D16)}$$

$$= 2.20 - 0.44 = 1.76\ \mu s$$

Therefore, choosing a network bias constant $T_{Network}$ of 1.35 μs and a signal transition time T_{Trans} of 1.75 μs ensures that the two bus signals will cross within the Common Mode Operating Range.

(R) CLASS B DATA COMMUNICATION NETW
--DETAILED HEADER FORMATS AND PH
ADDRESS ASSIGNMENTS—SAE J2178/1

Report of the SAE Vehicle Network for Multiplexing and Data Communications Standards Committee. Approved by the SAE Vehicle Network for Multiplex and Data Communications Standards Committee.

TABLE OF CONTENTS

1. Scope
2. References
2.1 Applicable Documents
3. Terms, Definitions, Abbreviations, and Acronyms
3.1 Terms and Definitions
3.2 Abbreviations and Acronyms
4. General Information
4.1 Part 1 Overview
4.2 In-Frame Response Field Formats
5. Single Byte Header Messages and Format
6. Consolidated Header Messages and Format
6.1 One Byte Form of the Consolidated Header Format
6.2 Three Byte Form of the Consolidated Header Format
7. Data Field Formats
7.1 Functional Data Fields Formats
7.2 Physical Data Field Formats
7.3 Extended Addressing
8. Physical Address Assignments
APPENDIX A—NETWORK ARCHITECTURES AND HEADER SIZ

1. Scope—This SAE Recommended Practice defines the contained in the header and data fields of non-diagnostic m interactive serial communications based on SAE J1850 Class B net different devices, and specifies the header fields, data fields, coding representations, and data positions used within messages.

The general structure of a SAE J1850 message frame, whic requires is shown in Figure 1. The structure of a SAE J1850 messa basic response is shown in Figure 2. Figures 1 and 2 also show t base fields defined by this document for non-diagnostic messages SAE J1979 for specifications of emissions related diagnostic mes and data fields. Refer to SAE J2190 for the definition of other diag fields. The description of the network interface hardware, inc addition, the electrical specifications, and the CRC byte are gi J1850.

FIGURE 1—SCOPE OF SAE J2178 FOR A SAE J1850 FRAME WIT FRAME RESPONSE (IFR)

FIGURE 2—SCOPE OF SAE J2178 FOR A SAE J1850 FRAME W FRAME RESPONSE (IFR)

SAE J1850 defines two and only two formats of message headers Single Byte header format and the Consolidated header for here. This document covers all of these formats and forms to f versions of messages which could be sent on a SAE J1850 network.

The document consists of four parts, each published separately.

SAE J2178/1 (This) Detailed Header Formats and Physica Assignments, describes the two allowed forms of message head Single Byte and Consolidated. It also contains the physical node ad requirements for the typical sub-systems of an automobile.

SAE J2178/2 (Future) Data Parameter Definitions, defines th Message data which may be exchanged on SAE J1850 (Class B) The parameter naming, ranges, and transfer functions are specified.

$$= -2.20 + \ln(1-(3.80/4.75)) = 1.37 \text{ ms}$$

$$T_{test,max}(\text{Bus}+) = -\Delta t + \ln(V_{st,max}/V_{sh,max})) \quad \text{(Eq. D12)}$$

$$= -2.20 + \ln(1.20/5.25) = 1.49 \text{ ms}$$

Choosing a $T_{test,max}$ of 1.35 µs satisfies both equations. Given a maximum network time constant of 1.35 µs, the signal transition time $T_{t,max}$ can be found by subtracting the time from $V_{st,min}$ to $V_{st,max}$ (for Bus –) or the time from $V_{st,max}$ to $V_{st,min}$ (for Bus +) from 2.20 µs. (See Equations D13 through D16.)

Bus (–):

$$T(V_{st,min} \text{ to } V_{st,max}) = -T_{test,max}(\ln(1-(V_{st,max}/V_{sq,max}))) \quad \text{(Eq. D13)}$$

$$= -1.35(\ln(1-(1.20/4.75))) = 0.39 \text{ µs}$$

$$T_{test,max} = 2.20 - T(V_{s}$$

$$= 2.20 - 0.39$$

Bus (+):

$$T(V_{st,max} \text{ to } V_{st,min}) = -T_{test,max}(l$$

$$= -1.35(\ln(3.$$

$$T_{test,max} = 2.20 - T(V_{s}$$

$$= 2.20 - 0.44$$

Therefore, choosing a network time const transition time $T_{t,max}$ of 1.75 µs ensures that the Common Mode Operating Range.

OMEGA EXHIBIT 2037

$V_{dominant}$ to $V_{dominant}$) (Eq. D1a)

$9 = 1.81\ \mu s$

$\ln(V_{dominant}/V_{dominant})$ (Eq. D1b)

$3.80/(5.25))) = 0.44\ \mu s$

$V_{dominant}$ to $V_{dominant}$) (Eq. D1c)

$4 = 1.76\ \mu s$

start $T_{dominant}$ of 1.35 μs and t
the two bus signals will cross

(R) CLASS B DATA COMMUNICATION NETWORK MESSAGES ---DETAILED HEADER FORMATS AND PHYSICAL ADDRESS ASSIGNMENTS---SAE J2178/1 JAN95 SAE Recommended Practice

Report of the SAE Vehicle Network for Multiplexing and Data Communication Standards Committee approved June 1992. Completely revised by the SAE Message Strategy Task Force of the SAE Vehicle Network for Multiplex and Data Communication Standards Committee January 1995.

TABLE OF CONTENTS

1. Scope
2. References
2.1 Applicable Documents
3. Terms, Definitions, Abbreviations, and Acronyms
3.1 Terms and Definitions
3.2 Abbreviations and Acronyms
4. General Information
4.1 Part 1 Overview
4.2 In-Frame Response Field Formats
5. Single Byte Header Messages and Format
6. Consolidated Header Messages and Format
6.1 One Byte Form of the Consolidated Header Format
6.2 Three Byte Form of the Consolidated Header Format
7. Data Field Formats
7.1 Functional Data Fields Formats
7.2 Physical Data Field Formats
7.3 Extended Addressing
8. Physical Address Assignments
APPENDIX A---NETWORK ARCHITECTURES AND HEADER SELECTION

1. Scope---This SAE Recommended Practice defines the information contained in the header and data fields of non-diagnostic messages for automotive serial communications based on SAE J1850 Class B networks. This document describes and specifies the header fields, data fields, field sizes, scaling, representations, and data positions used within messages.

The general structure of a SAE J1850 message frame without in-frame response is shown in Figure 1. The structure of a SAE J1850 message with in-frame response is shown in Figure 2. Figures 1 and 2 also show the scope of frame fields defined by this document for non-diagnostic messages. Refer to SAE J1979 for specifications of emissions related diagnostic message header and data fields. Refer to SAE J2190 for the definition of other diagnostic data fields. The description of the network interface hardware, basic protocol definition, the electrical specifications, and the CRC byte are given in SAE J1850.

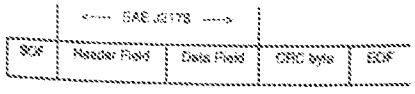


FIGURE 1---SCOPE OF SAE J2178 FOR A SAE J1850 FRAME WITHOUT IN-FRAME RESPONSE (IFR)

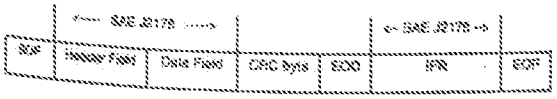


FIGURE 2---SCOPE OF SAE J2178 FOR A SAE J1850 FRAME WITH IN-FRAME RESPONSE (IFR)

SAE J1850 defines two and only two formats of message headers. They are the Single Byte header format and the Consolidated header format. The Consolidated header format has two forms, a Single Byte form and a three byte form. This document covers all of these formats and forms to identify the content of messages which could be sent on a SAE J1850 network.

This document consists of four parts, each published separately.

SAE J2178/1 (Titled: Detailed Header Formats and Physical Address Assignments) describes the two allowed forms of message header formats, Single Byte and Consolidated. It also contains the physical node address range assignments for the typical sub-systems of an automobile.

SAE J2178/2 (Titled: Data Parameter Definitions) defines the standard parametric data which may be exchanged on SAE J1850 (Class B) networks. The parameter scaling, ranges, and transfer functions are specified. Messages which refer to these parametric definitions shall always adhere to these parametric definitions. It is intended that at least one of the definitions for each parameter in this part matches the SAE J1979 definition.

SAE J2178/3 (Titled: Frame IDs for Single Byte Forms of Headers) defines the message assignments for the single byte header format and the one byte form of the consolidated header format.

SAE J2178/4 (Titled: Message Definition for Three byte Headers) defines the message assignments for the three byte form of the consolidated header format.

2. References

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

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

SAE J1213/1---Glossary of Vehicle Networks for Multiplex and Data Communication

SAE J1850---Class B Data Communication Network Interface

SAE J1930---Electrical/Electronic Systems Diagnostic Terms, Definitions, Abbreviations, and Acronyms

SAE J1979---E/E Diagnostic Test Modes

SAE J2190---Enhanced E/E Diagnostic Test Modes

2.1.2 ANSI/IEEE PUBLICATION---Available from ANSI, 11 West 42nd Street, New York, NY 10036-8002.

ANSI/IEEE 754-1985---IEEE Standard for Binary Floating Point Arithmetic

3. Terms, Definitions, Abbreviations, and Acronyms

3.1 Terms and Definitions

3.1.1 DATA (DATA FIELD)---Data and data field are used interchangeably in this document and they both refer to a field within a frame that may include bytes with parameters pertaining to the message and/or secondary ID and/or extended addresses and/or test modes which further defines a particular message content being exchanged over the network.

3.1.2 EXTENDED ADDRESS---The extended address is a means to allow a message to be addressed to a geographical location (such as geographic) or zone of the vehicle, independent of any node's physical address.

3.1.3 FRAME---A frame is one complete transmission of information which may or may not include an In-Frame Response. The frame is enclosed by the start of frame and end of frame symbols. For Class B networks, each frame contains one and only one message (see "message" definition below).

3.1.4 FRAME ID---The Frame ID is the header byte for the Single Byte Header format and the one byte form of the consolidated header format. The definition of the frame ID is found in SAE J2178/3. This header byte defines the target and source and content of the frame.

3.1.5 FUNCTIONAL ADDRESSING---Functional addressing allows a message to be addressed to one or more nodes on the network interested in that function. Functional addressing is intended for messages that may be of interest to more than a single node. For example, an exterior lamp "off" message could be sent to all nodes controlling the vehicle exterior lamps by using a functional address. The functional address consists of a primary ID and may include a secondary ID and may also include an extended address.

3.1.6 HEADER (HEADER FIELD)---The header (or header field, used interchangeably) is a one or three byte field within a frame which contains information about the message priority, message source and target addressing, message type, and in-frame response type.

3.1.7 IN-FRAME RESPONSE (IFR) TYPE---The IFR type identifies the form of the in-frame response which is expected within that message.

3.1.8 LOAD---The load command indicates the operation of directly replacing the current/existing value of a parameter with the parameter value(s) contained in the message.

3.1.9 MESSAGE---A message consists of all of the bytes of a frame including the delimiter symbols (SOF, EOD, EOF, NB).

3.1.10 MODIFY---The modify command indicates the operation of using the message data parameter value to change (e.g., increment, decrement, or toggle) the current/existing value.

3.1.11 PARAMETER—A parameter is the variable quantity included in some messages. The parameter value, scaling, offset, units, transfer function, etc., are unique to each particular message. (The assigned parameters are contained herein.)

3.1.12 PHYSICAL ADDRESSING—Physical addressing allows a message to be addressed to a specific node or to all nodes or to a non-existent, null node. The information in this message is of relevance only to a particular node, so the other nodes on the bus should ignore the message, except for the case of the "all nodes" address.

3.1.13 PRIMARY ID—The primary ID identifies the target for this functional message. This is the primary discriminator used to group functions into main categories.

3.1.14 PRIORITY—The priority describes the rank order and precedence of a message. Based upon the SAE J1850, Class B arbitration process, the message with the highest priority will win arbitration.

3.1.15 REPORT—A report indicates the transmission of parametric data values, based on: a change of state; a change of value; on a periodic rate basis; or as a response to a specific request.

3.1.16 REQUEST—A request is a command to, or a query for data, or action from another node on the network.

3.1.17 RESPONSE DATA—The response data is the information from a node on the network in response to a request from another node on the network. This may be an in-frame response or a report type of message.

3.1.18 SECONDARY ID—The secondary ID (along with the primary ID or Frame ID) identifies the functional target node for a message. The purpose of the secondary ID field within the frame is to further define the function or action being identified by the primary ID.

3.2 Abbreviations and Acronyms

A/C	-	Air Conditioning
ASC	-	ASCII Encoded SLOT
BCD	-	Binary Coded Decimal (BCD) SLOT
BMM	-	Bit Mapped with Mask SLOT
BMP	-	Bit Mapped without Mask SLOT
CRC	-	Cyclic Redundancy Check
CS	-	Checksum
DTC	-	Diagnostic Trouble Code
EOD	-	End of Data
EOF	-	End of Frame
ERR	-	Error Detection
HVAC	-	Heating, Ventilation, Air Conditioning
ID	-	Identifier
IFR	-	In-Frame Response
LSB	-	Least Significant Bit / Byte
MSB	-	Most Significant Bit / Byte
NB	-	Normalization Bit
PID	-	Parameter Identification (number, NOT the primary ID, See Section 8)
PKT	-	Multiple Parameter Packet SLOT
PRN	-	Parameter Reference Number
SED	-	State Encoded SLOT
SFP	-	Signed Floating Point (Scientific Notation) SLOT
SLOT	-	Scaling, Limit, Offset, and Transfer Function (See Section 7)
SNM	-	2's Complement Signed Numeric SLOT
SOF	-	Start of Frame
UNM	-	Unsigned Numeric SLOT
VIN	-	Vehicle Identification Number

4. General Information

4.1 Part 1 Overview—These messages defined by this first part document are specified for networks using single byte headers as consolidated one and three byte headers as specified in SAE J1850. Sections 3 and 6 of SAE J2178/1 provide the system architecture for the different possible headers used in Class B network communication (see Appendix A for supporting discussion). Section 7 of SAE J2178/1 defines the data fields used by the different header byte formats. Section 8 of SAE J2178/1 defines the physical address assignments.

Figure 3 shows an overview of this part (Part 1) which encompasses the different possible messages and their components parts.

SAE J1850 defines two and only two formats of message headers. They are the Single Byte Header format and the Consolidated header format. The Consolidated header format has two forms, identified by the value of the H Bit. The two forms are: a one byte form and a three byte form. The information in the header field for both formats contains target, source, priority and message type information, while the data field contains additional addressing and/or parametric information and/or diagnostic test modes. This information is explicitly defined in some headers and implicitly defined in others. Messages defined by this document (Parts 1, 2, 3, and 4) are classified generally into two types:

a. Requests, that is, commands (load or modify) or queries for data, and
b. Responses, that is, reports or acknowledgements.

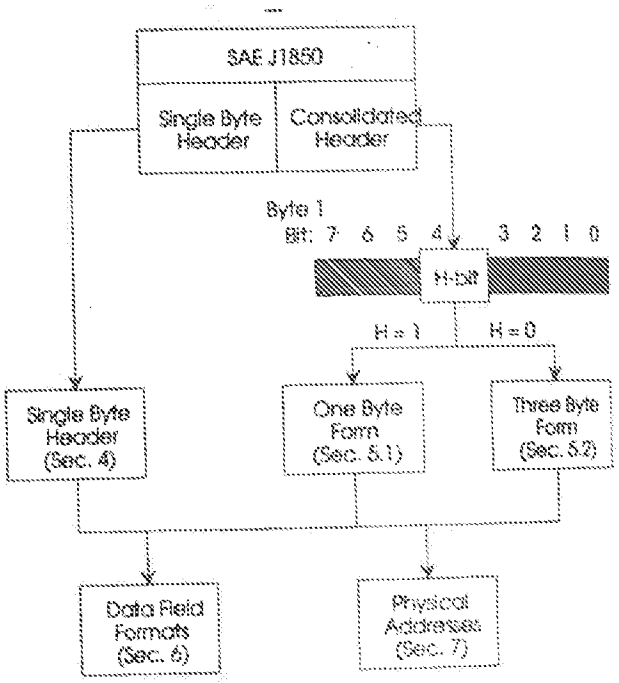


FIGURE 3—PART 1 OVERVIEW

When a node generates a request, the target nodes which are responsible for the requested data or function must respond by reporting the requested information or by performing the requested function. For responses (that is, reports or acknowledgements), data information that a node responds with may have been previously requested by another node, or reported by the node when the desired information has changed, or reported by the node on a periodic basis.

SAE J2178/1 describes the overall structure of messages. In total, parts 1, 2, 3, and 4:

a. Fully define SAE (automotive industry) standard messages.
b. Reserve messages for future SAE standardization.
c. Reserve messages for manufacturers to allocate, which are typically unique or proprietary to that manufacturer.

In order to comply with this document, implementations need to use its defined messages on SAE J1850 networks in the exact way that they are defined here. However, there are a large number of message codes that are reserved for each manufacturer to independently allocate.

4.2 In-Frame Response Field Formats—The total number of bytes in the frame (not including frame delimiters) is 12, including the header (1 or 3 depending on header type), data (both in the message and IFR), and single byte CRC. Therefore, the total number of message and IFR data bytes can be 10 if using a single byte header or the one byte form of the consolidated header, or 8 bytes if using the three byte form of the consolidated header.

4.2.1 IN-FRAME RESPONSE TYPE 0—The in-frame response type 0 is used to indicate the form without any in-frame response.

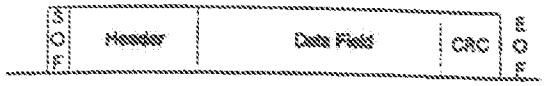
4.2.2 IN-FRAME RESPONSE TYPE 1—The in-frame response type 1 is a single byte response from a single responder. The response byte shall be the physical address of a receiver of the message. No CRC byte is included for this response data.

4.2.3 IN-FRAME RESPONSE TYPE 2—The in-frame response type 2 is a single byte response from multiple responders. The response byte(s) shall be the physical address of the receiver(s) of the message. No CRC byte is included in the response data.

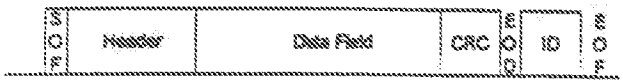
4.2.4 IN-FRAME RESPONSE TYPE 3—The in-frame response type 3 is a multiple byte response from a single responder. The response bytes shall be data (generally not its address) from a single responder. The second CRC byte is included for the data integrity of the response data. The actual in-frame response data shall be one byte in length, as a minimum.

Page 705 of 1656 OMEGA EXHIBIT 2037

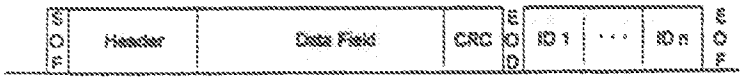
Figure 4 illustrates the four IFR types.



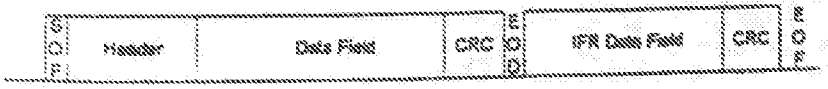
Type 0 - None



Type 1 - Single Byte From a Single Responder



Type 2 - Single Byte From Multiple Responders



Type 3 - Multiple Bytes From a Single Responder

FIGURE 4—TYPES OF IN-FRAME RESPONSE

5. *Single Byte Header Messages and Format*—For single byte header messages, the entire byte is used to define the message identifier (ID) as shown in Figure 5. This allows up to 256 unique message identifiers to be defined. Standard message identifiers that utilize this header format are found in SAE J2178/3.

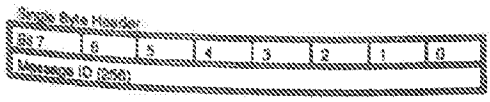


FIGURE 5—SINGLE BYTE HEADER

All single byte header messages utilize one of the four in-frame response (IFR) types (see Figure 4).

6. *Consolidated Header Messages and Format*—The consolidated header format includes both a one byte form and a three byte form.

6.1 One Byte Form of the Consolidated Header Format—The one byte form utilizes 7 bits for the message identifier thereby allowing up to 128 distinct IDs. The H bit (bit 4) is always a logic "1" signifying the one byte form of the consolidated header. Figure 6 illustrates this message header form. Standard message identifiers that utilize this header form are defined in SAE J2178/3.

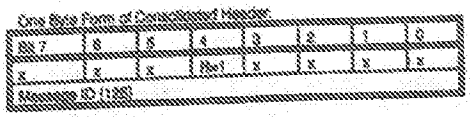


FIGURE 6—ONE BYTE FORM OF CONSOLIDATED HEADER

In order to accommodate a one byte header form and a three byte header form on the same network, the header type bit (H bit) in the first byte of the message has been defined to indicate the header form. This bit is defined in Table 1.

TABLE 1—H BIT DEFINITION

H Bit	Header Byte Form
0	Three Byte Form
1	One Byte Form

OMEGA EXHIBIT 2037

All one byte header form messages of the consolidated header format utilize one of the four in-frame response (IFR) types (see Figure 4).

6.2 Three Byte Form of the Consolidated Header Format—This header form utilizes the first three bytes of the message. The H bit (bit 4) is always a logic "0" signifying the three byte form. Standard message identifiers that utilize this header form are defined in SAE J2178/4. The remaining seven bits of the first byte contain information about priority (PPP) and message type (KYZZ). The second byte contains the target address information. The target can be either functionally addressed or physically addressed. The third byte contains the physical address of the source of the message. Arbitration is always resolved by the end of the third byte, since the source address must be unique. Figures 7 and 8 illustrate this message header form.

Three Byte Form of Consolidated Header

Byte 1	Byte 2	Byte 3
See Figure 8	Target Address	Source Address

FIGURE 7—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	Definition	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	00	See Table 6
		01	
		10	
		11	

FIGURE 8—FIRST BYTE OF THREE BYTE FORM OF CONSOLIDATED HEADER

All three byte header messages utilize one of the four in-frame response (IFR) types (see Figure 4, 3.2).

6.2.1 PRIORITY/TYPE-BYTE 1—The priority/type byte contains information about priority, in-frame response, addressing type, and type modifier. Each of the field definitions is described in the following paragraphs.

6.2.1.1 Priority (PPP Bits)—The priority field is three bits in length and immediately proceeds the header type (H) bit. The priority bit definition is shown in Table 2. The priority bit assignments for a particular message are manufacturer specific and are not assigned by SAE J2178.

TABLE 2—PRIORITY FIELD ASSIGNMENTS

PPP Bits	Priority	Level
000	0	Highest
001	1	.
010	2	.
011	3	.
100	4	.
101	5	.
110	6	.
111	7	Lowest

6.2.1.2 Header Type (H Bit)—In order to accommodate a one byte header form and a three byte header form on the same network, the header type bit (H bit) in the first byte of the message has been defined to indicate the header form. This bit is defined in Table 3.

TABLE 3—H BIT DEFINITION

H Bit	Head Byte Form
0	Three Byte Form
1	One Byte Form

6.2.1.3 In-Frame Response (K Bit)—The necessity for in-frame response is encoded into a single bit in the priority/ type byte. This bit definition is shown in Table 4.

6.2.1.4 Addressing Type (Y Bit)—Message addressing is encoded with a single bit in the priority/type byte. This bit definition is shown in Table 5.

TABLE 4—"K" BIT ASSIGNMENTS

K Bit	In-Frame Response
0	Required
1	Not Allowed

TABLE 5—"Y" BIT ASSIGNMENTS

Y Bit	Addressing Type
0	Functional
1	Physical

6.2.1.5 Type Modifier (ZZ Bits)—The type modifier is encoded as a two bit field (ZZ) and is used in conjunction with the in-frame response bit (K) and the address type bit (Y) to define sixteen message types, see Table 6.

TABLE 6—THE SIXTEEN MESSAGE TYPES

Msg Type	KYZZ	Response (K bit)	Addressing (Y bit)	IFR Type	Message Type (Name)
0	0000	Required	Functional	2	Function
1	0001	Required	Functional	1	Broadcast
2	0010	Required	Functional	2	Function Query
3	0011	Required	Functional	3	Function Read
4	0100	Required	Physical	1	Node-to-Node
5	0101	Required	Physical	—	Reserved - MFG
6	0110	Required	Physical	—	Reserved - SAE
7	0111	Required	Physical	—	Reserved - MFG
8	1000	Not Allowed	Functional	0	Function Command / Status
9	1001	Not Allowed	Functional	0	Function Request / Query
10	1010	Not Allowed	Functional	0	Function Ext. Command / Status
11	1011	Not Allowed	Functional	0	Function Ext. Request / Query
12	1100	Not Allowed	Physical	0	Node-to-Node
13	1101	Not Allowed	Physical	0	Reserved - MFG
14	1110	Not Allowed	Physical	0	Acknowledgement
15	1111	Not Allowed	Physical	0	Reserved - MFG

NOTES:
1. Functional addresses for the three byte form of the consolidated header are defined in SAE J2178/4. Physical address ranges are defined in Section 7 of this part.
2. Message types 8 and 9 use functional data format #2 only; message types 10 and 11 use functional data format #3 only.
3. Reserved - SAE indicates reserved for future SAE Committee action. Reserved - MFG indicates that manufacturers are allowed to allocate these definitions without requiring any commonality between motor vehicle manufacturers.

6.2.2 TARGET ADDRESS-BYTE 2—The second byte of the three byte form of the consolidated header format contains either a functional or physical target address. The physical address assignments are found in Section 7 of this part, while functional message address assignments are in SAE J2178/4.

Functional addresses are assigned in pairs where the only difference between the ID values is the least significant bit (W bit). Figure 9 illustrates the functional target address with W bit.

Bit 7	6	5	4	3	2	1	0
X	X	X	X	X	X	X	W
Primary ID (128 max)							

FIGURE 9—FUNCTIONAL TARGET ADDRESS

The W bit is logic "0" to signify a Command target and logic "1" to signify a Status target. This bit is defined in Table 7.

TABLE 7—W BIT DEFINITION

W Bit	Functional Target Address Type
0	Command
1	Status

6.2.3 SOURCE ADDRESS-BYTE 3—The third byte of the three byte format of the consolidated header format is the physical address of the source of the message. Physical address assignments are found in Section 8. These physical address assignments shall be unique for each node of a network.

7. Data Field Formats—In both message header formats, single byte and consolidated, the data field can usually be encoded in the same way. This section briefly describes the different ways that information can be formatted in the data field. The data field immediately follows the header field. The number of bytes in this field will vary, based upon the content of the header field. The maximum data field length is limited by the requirements of SAE J1850. Because of differences in functionally and physically addressed messages or with in-frame response data, these cases are defined separately.

7.1 Functional Data Field Formats

Page 707 of 1656 OMEGA EXHIBIT 2037

7.1.1 FUNCTIONAL DATA FIELD FORMAT 0—One of the functional data field formats is, in fact, no additional bytes of data (an empty data field). The message consists of the header, error checking byte, and in-frame response bytes. This is the format used for functional message types 2 and 3. Because the data field does not actually exist but to allow referencing in other parts of this document, it has been identified as the functional data field format 0.

7.1.2 FUNCTIONAL DATA FIELD FORMAT 1—In the simplest case including data (format 1), the data field contains only parametric data. The first byte of the data field in this case contains the most significant byte of data. The data field must contain one byte as a minimum. Figure 10 illustrates this message format. This data field format may be used for message types 0 and 1 only.

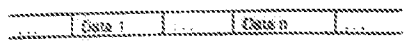


FIGURE 10—FUNCTIONAL DATA FIELD FORMAT 1

7.1.3 FUNCTIONAL DATA FIELD FORMAT 2—In a data field format 2 message, the data field contains a byte which is used to further define the target function being addressed. In this format type, the data field would appear as shown in Figure 11. This data format may be used for message types 0, 1, 8 and 9.

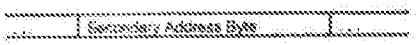


FIGURE 11—FUNCTIONAL DATA FIELD FORMAT 2

The secondary address byte consists of a parameter/quantity bit (Q bit) in which binary data (such as, on/off or yes/no) can be encoded. There is a listing of the possible uses for this bit in SAE J2178/4. The control bit (C bit) is used to distinguish between an immediate load of data or a modify of the current data for command messages, or to distinguish between request/report and query message operations. The remaining six bits specify a secondary ID address. The order of these bits within the secondary address byte is shown in Figure 12.

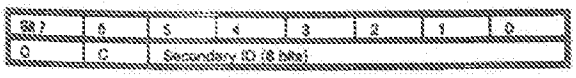


FIGURE 12—SECONDARY ADDRESS BYTE FORMAT

In many cases, a single data bit (i.e., the Q bit) is not adequate to define the data parameter being sent. In this case, the identifier field is followed by an additional data field as illustrated in Figure 13. The combination of the primary and secondary addresses defines whether additional data is used by that message.

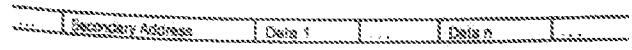


FIGURE 13—FUNCTIONAL DATA FIELD FORMAT 2, WITH DATA BYTES

7.1.3.1 The Parameter/Quantity Bit (Q bit)—The Q bit is used to represent single, binary values. Refer to SAE J2178/4 for a list of valid uses for the Q bit.

7.1.3.2 The Control Bit (C bit)—The C bit represents an action or operation to be taken with the associated data values. Table 8 shows how the W and C bits are used in conjunction with the eight functionally addressed message types (0-3, and 8-11) to define a particular message operation.

Modify messages adjust (e.g., increment/decrement) or toggle the state of existing data. Load messages replace current or existing data. Request messages "ask" for existing status or command data. Report messages "tell" existing status. Query messages "ask" for the receivers of a message without asking for the associated data.

7.1.3.3 The Secondary ID—The secondary identification field is used to further identify the particular function or operation being addressed by this message. It is used to distinguish a function when the primary ID is not sufficient, or to define a specific operation to be performed by the function addressed by the primary ID. These secondary identification addresses are assigned in SAE J2178/3 and SAE J2178/4.

7.1.4 FUNCTIONAL DATA FIELD FORMAT 3—In a data field format 3 message, depending on the particular primary and secondary ID, the data field may also contain an extended address byte which defines the geographical location within the vehicle of the target function being addressed. This data field format may be used for message types 0 and 1 and must be used for message types 10 and 11. In this data field type, the data field appears as shown in Figure 14.

TABLE 8—MESSAGE OPERATIONS

Msg Type	XY2Z	W	C	Message Type	Message Operation
0	0000	0	0	Function	Load Command
		0	1		Modify Command
		1	0		Report Status
		1	1		MFG Specific
1	0001	0	0	Broadcast	Load Command
		0	1		Modify Command
		1	0		Report Status
		1	1		MFG Specific
8	1010	0	n/a	Function Query	Command Query
		1	n/a		Status Query
9	1011	n/a	n/a	Function Read	Not Applicable
8	1000	0	0	Function Command /Status	Load Command
		0	1		Modify Command
		1	0		Report Status
		1	1		MFG Specific
9	1001	0	0	Function Request / Query	Status Request
		0	1		Report Acknowledge
		1	0		Command Request
		1	1		Function Query
10	1010	0	0	Function Ext. Command / Status	Load Command Extended
		0	1		Modify Command Extended
		1	0		Report Status Extended
		1	1		MFG Specific
11	1011	0	0	Function Ext. Request / Query	Status Request Extended
		0	1		Report Acknowledge Extended
		1	0		Command Request Extended
		1	1		Function Query Extended

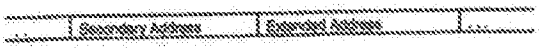


FIGURE 14—FUNCTIONAL DATA FIELD FORMAT 3

The extended address byte is used to determine where, geographically on a vehicle, a particular function is located. The exact definition of the extended address values can be found in 7.3. The secondary address in Figure 14 is used as defined in 7.1.3.

As in the other data field formats, a parameter data field may also be needed and in this case it is then appended to the end of the other identifiers. This format is shown in Figure 15.

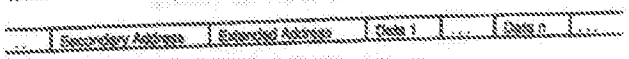


FIGURE 15—FUNCTIONAL DATA FIELD FORMAT 3, WITH DATA BYTES

7.1.5 FUNCTIONAL DATA FIELD FORMAT 4—In this data field format message, the data field contains a byte which defines the diagnostic test mode of the target function being addressed. In this type, the data field would appear as shown in Figure 16. This data format may be used for message types 0, 1, 8 and 9.

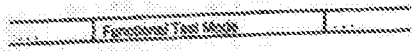


FIGURE 16—FUNCTIONAL DATA FIELD FORMAT 4

The test mode byte is used to determine which diagnostic function is involved. It may then be followed by parameter data fields. In this case, the additional data bytes follow the test mode byte. This format is shown in Figure 17. This is the format for functionally addressed diagnostic messages such as those found in SAE J1979.

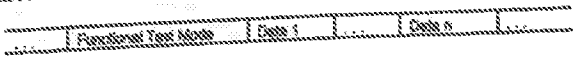


FIGURE 17—FUNCTIONAL DATA FIELD FORMAT 4, WITH DATA BYTES

Page 708 of 1656 OMEGA EXHIBIT 2037

7.2 Physical Data Field Formats—The previous section (7.1) defined the data field formats for functionally addressed messages. This section (7.2) defines the data field formats for physically addressed messages.

7.2.1 PHYSICAL DATA FIELD FORMAT 0—One of the physical data field formats is, in fact, no additional bytes of data (an empty data field). The message consists of the header, error checking byte, and may be with or without in-frame response bytes. This is the format used for the acknowledgement message type. This message type simply confirms to another node that the message has been received correctly. Because this data field does not actually exist but to allow referencing in other parts of this document, it has been identified as the physical data field format 0.

7.2.2 PHYSICAL DATA FIELD FORMAT 1—Physical data field format 1 is generally associated with the node-to-node message types. This message type is the one utilized for enhanced E/E diagnostic test modes (see SAE J2190). This format assumes the three byte form of the consolidated header format. The single byte format and the one byte form of the consolidated header format are covered in physical data field format 2 (see 7.2.3). Many of the specific diagnostic messages are defined in SAE J2190. This description of the format is consistent with SAE J2190 but expands the definition to allow the format to be used in other messages as well. In particular, the manufacturer specific applications of this node-to-node message are expected to follow this format. The basic format is similar to the functional data field format 4. The format is shown in Figure 18.

. . .	Physical Test Mode	. . .

FIGURE 18—PHYSICAL DATA FIELD FORMAT 1

The format will often include data bytes as shown in Figure 19. The contents of the test mode byte indicate if additional data bytes are used.

. . .	Physical Test Mode	Data 1	. . .	Data n	. . .

FIGURE 19—PHYSICAL DATA FIELD FORMAT 1, WITH DATA BYTES

The physical test mode byte details are shown SAE J2190.

7.2.3 PHYSICAL DATA FIELD FORMAT 2—In order to maximize commonality between the different header byte formats, the physical data field format 2 is essentially the same as physical data field format 1 with the insertion of the physical target address byte ahead of the physical test mode byte. This allows the single byte header format and the one byte form of the consolidated header format to operate consistently with the three byte header form. The format is shown in Figures 20 and 21 for the two cases, without and with additional data bytes, respectively

. . .	Physical Target Address	Physical Test Mode	. . .

FIGURE 20—PHYSICAL DATA FIELD FORMAT 2

. . .	Physical Target Address	Physical Test Mode	Data 1	. . .	Data n	. . .

FIGURE 21—PHYSICAL DATA FIELD FORMAT 2, WITH DATA BYTES

7.3 Extended Addressing—Extended addressing defines an extended (geographical) location in the vehicle. The upper two bits of the extended address (RR) are used to allow up to four different types of extended addressing. Table 9 shows these bit assignments.

TABLE 9—EXTENDED ADDRESS TYPES

RR	Type
00	Geographical Addressing
01	Reserved - SAE
10	Reserved - MFG
11	Reserved - MFG

The extended address format for geographical addressing is encoded as shown in Figure 22.

Bit 7	6	5	4	3	2	1	0
RR = 00		XXX = Row #			YYY = Col #		

FIGURE 22—EXTENDED ADDRESSING

The codes XXX = 000 (for rows) and YYY = 000 (for columns) indicate that ALL rows and/or ALL columns are indicated. In other words, to address all of the items in a specific row, regardless of which column, use XXX = 000. For all items in the same column, independent of which row, use YYY = 000. Using all combinations of XXX and YYY, there are 64 total geographical zones that can be addressed. Table 10 shows the different combinations available.

TABLE 10—EXTENDED ADDRESS AREAS

XXX Range	YYY Range	Description	# areas
000	000	ALL Rows and Columns	1
000	001 - 111	ALL Rows x 7 Columns	7
001 - 111	000	ALL Columns x 7 Rows	7
001 - 111	001 - 111	49 Distinct Areas	49
Total	—	—	64

SAE J2178/4 lists the valid extended address assignments based on message.

A map illustrating the 49 zones of the vehicle is shown in Figure 23. It generally represents a top view of the vehicle and supports both Left/Right and Driver/Passenger side references.

XXX \ YYY	001	010	011	100	101	110	111
001	Left Side Front Surface	Driver Side Front Surface	Left Center Front Surface	Center Point Front Surface	Right Center Front Surface	Passenger Side Front Surface	Right Side Front Surface
010	Left Side Under Hood	Driver Side Under Hood	Left Center Under Hood	Center Point Under Hood	Right Center Under Hood	Passenger Side Under Hood	Right Side Under Hood
011	Left Side Aft Bulkhead	Driver Side Aft Bulkhead	Left Center Aft Bulkhead	Center Point Aft Bulkhead	Right Center Aft Bulkhead	Passenger Side Aft Bulkhead	Right Side Aft Bulkhead
100	Left Side Aft "A" Pillar	Driver Side Aft "A" Pillar	Left Center Aft "A" Pillar	Center Point Aft "A" Pillar	Right Center Aft "A" Pillar	Passenger Side Aft "A" Pillar	Right Side Aft "A" Pillar
101	Left Side Mid Vehicle	Driver Side Mid Vehicle	Left Center Mid Vehicle	Center Point Mid Vehicle	Right Center Mid Vehicle	Passenger Side Mid Vehicle	Right Side Mid Vehicle
110	Left Side Trunk	Driver Side Trunk	Left Center Trunk	Center Point Trunk	Right Center Trunk	Passenger Side Trunk	Right Side Trunk
111	Left Side Rear Surface	Driver Side Rear Surface	Left Center Rear Surface	Center Point Rear Surface	Right Center Rear Surface	Passenger Side Rear Surface	Right Side Rear Surface

NOTE—Refer to J2178/4 for range of address explanation.

FIGURE 23—EXTENDED ADDRESS MAP

Page 709 of 1656 OMEGA EXHIBIT 2037

8. Physical Address Assignments—The physical address assignment ranges for nodes on a network are shown in Table 11. It is important to note that node address assignments on any network must be unique. In other words, no two nodes can have the same physical address assignment.

TABLE 11—NODE PHYSICAL ADDRESS ASSIGNMENTS

Node Category	Address (hex)	# of Nodes
Powertrain Controllers:	00 - 1F	32
Integration / Manufacturer Expansion	00 - 0F	16
Engine Controllers	10 - 17	8
Transmission Controllers	18 - 1F	8
Chassis Controllers:	20 - 3F	32
Integration / Manufacturer Expansion	20 - 27	8
Brake Controllers	28 - 2F	8
Steering Controllers	30 - 37	8
Suspension Controllers	38 - 3F	8
Body Controllers:	40 - C7	136
Integration / Manufacturer Expansion	40 - 57	24
Restraints	58 - 5F	8
Driver Information / Displays	60 - 6F	16
Lighting	70 - 7F	16
Entertainment / Audio	80 - 8F	16
Personal Communications	90 - 97	8
Climate Control (HVAC)	98 - 9F	8
Convenience (Doors, Seats, Windows, etc.)	A0 - BF	32
Security	C0 - C7	8
Future Expansion:	C8 - CF	8
Manufacturer Specific:	D0 - EF	32
Off-Board Testers / Diagnostic Tools	F0 - FD	14
All Nodes:	FE	1
Null Node:	FF	1

APPENDIX A
NETWORK ARCHITECTURES AND HEADER SELECTION

A.1 Architectures of Networks—A wide variety of network topologies can be envisioned by network designers. The message structure described in this document is very flexible and useful in exchanging information between network nodes. The following discussion describes two network architectures that are likely configurations to use this message definition set:

a. A single network architecture

b. A multiple network architecture

Which of the different message definitions to use for these two network architectures is left as the system designer's choice, because the selection would be application specific. It should be noted that the hardware that supports these two message structures is generally not interchangeable. It is recommended that care be taken in choosing which message definition to use because the selection is generally irreversible because of these hardware limitations.

Consideration must be given by the network designer as to whether a single network architecture or a multiple network architecture, within the same vehicle, is preferable for that application. For example, a multiple network architecture could be based on one network optimized around data communication (Class B) protocol requirements, and another network optimized around sensor type (Class A) multiplexing requirements. The Class B network may be characterized such that time is a significant characteristic of the protocol where the functional "broadcast" type of message strategy can most effectively be used. The functional messages strategy can, if required, define the source or destination of a particular message by making it part of the message. However, it is unnecessary to designate or specify the source or destination of functional broadcast type messages. Reception becomes the exclusive responsibility of the receiving node.

A Class A network could handle the vehicle's event-driven multiplexing requirements. A single network architecture is based on the concept of a network that handles both Class A and B requirements. It should be clear that both network architectures must be cost effective for the application and the specific nodes on each network.

In Class B communications, the network consists of the interconnection of intelligent nodes such as: an engine controller, a body computer, a vehicle instrument cluster, and other modules. Such a network normally does not significantly reduce the base vehicle wiring but provides an inter-module data communications capability for distributed processing. The data shared between modules may be repetitive in nature and sometimes requires handshaking between modules or acknowledgment of data reception. As a result of handling the repetitive data and response type data, a network can be optimized around functional addressing. Functional addressing sends data on the network which can be received by one or more nodes without regard to the physical location of the module but only by their "interest" in those specific functions. In general, the transmitting node doesn't care which, if any, nodes receive the data it is sending. When physical addressing is required in a data communications (Class B) network, it is usually for vehicle diagnostic purposes and can be easily handled without reducing network bandwidth. See Section 6 for a discussion of these two types of message addressing.

In Class A communications, the network generally consists of the interconnection of limited intelligence nodes, often simply sensors or actuators. These Class A networks can significantly reduce the base vehicle wiring as well as potentially remove redundant sensors from the vehicle. The data shared between nodes in this case are generally event driven in nature. In most vehicles, the number of event driven signals predominates but they are only needed infrequently. The message to "turn headlamps on," for example, can be easily seen as event driven. Because these messages are infrequent (only sent once when the signal changes), they generally require acknowledgment, either within the same message or a separate handshake / response message. Both of these approaches are supported by SAE J1850 and in this document.

The single network architecture carries both the Class A and Class B messages on one network. The characteristics of both time critical and event driven messages must be accommodated on a message by message basis. In general, this level of complexity will need the flexibility of the consolidated header structure. For some applications, however, the single byte header may be adequate and is in no way limited by this specification.

The multiple network architecture tends to separate the Class A messages from the Class B messages and optimize each network and node interface for the specific characteristics of each network Class. The time critical messages could be exchanged on one network while the event driven messages went on another. For example, the data communication (Class B) repetitive messages can be handled on one network and the sensor and control (Class A) multiplexing requirements on another network. This architecture requires both networks to work together to achieve the total vehicle network requirements. If information is needed between the multiple networks, care must be exercised to meet the needs of each of the networks. This concept of multiple networks is not limited to two, but can be extended to several separate networks, if desired.

A.2 Header Selection—The selection of headers is dependent on a number of factors. Hardware cost is related to the complexity of interface hardware required, as opposed to level of software required to implement the system.

The three byte form of the consolidated header offers systems designers advantages over the single byte only header format. More bits are available for use in assigning message identifiers, priorities, message types, etc. In addition, the three byte header is not restricted to 256 addresses. The "H" bit of the consolidated header format is used to indicate the use of one byte or three byte header messages which provides flexibility for future applications. This consolidated format generally requires increased hardware implementations because of the variety of message forms allowed. However, because of the increased hardware definition, software complexity and coding error problems are reduced. The consolidated header format offers the flexibility to readily handle both Class A and Class B requirements, matching header length to each specific message, as needed.

The single byte only header format is a simple and efficient method of identifying messages in a Class B data communications optimized network. This type of header can be simply called the Message Identifier or ID. The ID becomes the name of the message that is broadcast to all the other nodes on the network. The message ID concept supports a very easily understood message protocol leading to the utilization of a simple hardware interface circuit.

The single byte only header format in a Class B data communications environment is required to support a repetitive message strategy and manage network bandwidth efficiently. The results can yield an average message length of less than four bytes. Message overhead can be kept small and message latency minimized to improve the network's capability for handling time critical data. Another resulting feature of this method of message identification is that arbitration events are reduced (resolved within the first byte) and the need to carefully assign message priority is reduced.

As in the case of network architectures above, the choice of single byte header format or consolidated header format is left to the system designer. The choice must be made for each separate network for each application but this offers the ability to select which characteristic is important for the specific case.

Page 710 of 1656 OMEGA EXHIBIT 2037

CLASS B DATA COMMUNICATION NETWORK MESSAGES PART 2: DATA PARAMETER DEFINITIONS— SAE J2178/2 JUN93

SAE Recommended Practice

Report of the Vehicle Network for Multiplexing and Data Communications Standards Committee approved June 1993.

TABLE OF CONTENTS

1. Scope
1.1 Standardized Parameter Definitions
2. References
2.1 Applicable Documents
2.1.1 SAE Publications
2.1.2 ANSI Publication
2.2 Related Publications
2.3 Terms and Definitions
2.4 Abbreviations and Acronyms
3. General Information
3.1 Part 2 Overview
3.2 How To Use This Document
4. Parameter Reference Number (PRN) Structure
5. Parameter Formats
5.1 Bit Mapped Parameters
5.1.1 Bit Mapped Data Without Mask Byte(s)
5.1.2 Bit Mapped Data With Mask Byte(s)
5.1.3 Bit Values
5.2 Byte (8 Bit) Parameters
5.3 Word (16 Bit) Parameters
5.4 Multi-Byte (>16 Bit) Parameters
5.5 Multiple Parameter Packets
6. Specific Parameter (PRN) Assignments
6.1 Specific Parameters
7. Scaling, Limit, Offset, and Transfer Function (SLOT) Definitions
7.1 Multiple Parameter Packeted (PKT) SLOTs
7.1.1 Multiple Parameter Packeted Assignments
7.2 Bit Mapped Without Mask (BMP) SLOTs
7.2.1 Bit Mapped Without Mask Parameter Assignments
7.3 Bit Mapped With Mask Bytes (BMM) SLOTs
7.3.1 Bit Mapped With Mask Parameter Assignments
7.4 Unsigned Numeric (UNM) SLOTs
7.4.1 Unsigned Numeric Variable Assignments
7.5 2's Complement Signed Numeric (SNM) SLOTs
7.5.1 2's Complement Signed Numeric Variable Assignments
7.6 State Encoded (SED) SLOTs
7.6.1 State Encoded Variable Assignments
7.7 ASCII Encoded (ASC) SLOTs
7.7.1 ASCII Encoded Variable Assignments
7.7.2 ASCII Character Set
7.8 Binary Coded Decimal (BCD) SLOTs
7.8.1 Binary Coded Decimal (BCD) Variable Assignments
7.9 Signed Floating Point (Scientific Notation) (SFP) SLOT
7.9.1 Signed Floating Point Variable Assignment
8. Multiple Frame, Single Parameter Format

1. Scope—This SAE Recommended Practice defines the information contained in the header and data fields of non-diagnostic messages for automotive serial communications based on SAE J1850 Class B networks. This document describes and specifies the header fields, data fields, field sizes, scaling, representations, and data positions used within messages.

The general structure of a SAE J1850 message frame without in-frame response is shown in Figure 1. The structure of a SAE J1850 message with in-frame response is shown in Figure 2. Figures 1 and 2 also show the scope of frame fields defined by this document for non-diagnostic messages. Refer to SAE J1979 for specifications of emissions-related diagnostic message header and data fields. Refer to SAE J2190 for the definition of other diagnostic data fields. The description of the network interface hardware, basic protocol definition, the electrical specifications, and the CRC byte are given in SAE J1850.

SAE J1850 defines two and only two formats of message headers. They are the Single Byte header format and the Consolidated header format. The consolidated header format has two forms, a single byte form and a three byte form. This document covers all of these formats and forms to identify the contents of messages which could be sent on a SAE J1850 network.

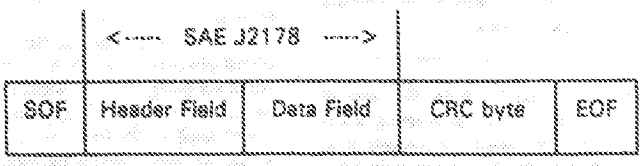


FIGURE 1—SCOPE OF SAE J2178 FOR A SAE J1850 FRAME WITHOUT IN-FRAME RESPONSE (IFR)

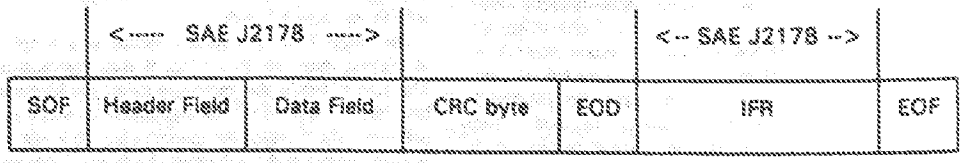


FIGURE 2—SCOPE OF SAE J2178 FOR A SAE J1850 FRAME WITH IN-FRAME RESPONSE (IFR)

This document consists of four parts, each published separately.

Part 1 of SAE J2178 (Titled: Detailed Header Formats and Physical Address Assignments) describes the two allowed forms of message header formats, single byte and consolidated. It also contains the physical node address range assignments for the typical subsystems of an automobile.

Part 2 of SAE J2178 (this part, Titled: Data Parameter Definitions) defines the standard parametric data which may be exchanged on SAE J1850 (Class B) networks. The parameter scaling, ranges, and transfer functions are specified. Messages which refer to these parametric definitions shall always adhere to these parametric definitions. It is intended that at least one of the definitions for each parameter in this part match the SAE J1979 definition. The details of this part are fully described in 3.1.

Part 3 of SAE J2178 (Titled: Frame IDs for Single Byte Forms of Headers) defines the message assignments for the single byte header format and the one byte form of the consolidated header format.

Part 4 of SAE J2178 (Titled: Message Definition for Three Byte Headers) defines the message assignments for the three byte form of the consolidated header format.

1.3 Standardized Parameter Definitions—The parameters used to describe data variables are one of the most important functions of this document. To achieve commonality of messages in Class B networks, the data parameters must become standardized. This applies to data parameter definitions for use during normal vehicle operations as well as during diagnostic operations. By using common parameter definitions for non-diagnostic and diagnostic functions on the network, the modules which form the network can maintain one image or description of a data parameter.

Where parameters have been defined in the Diagnostic Test Modes documents (SAE J1979 and J2190), such as Parameter Identifiers for diagnostic purposes, the definitions in Part 2 of this document match the diagnostic definition.

SAE J2178, Part 2 defines the parameters to be used for non-diagnostic and diagnostic data format definitions. For new parameter definitions which are needed in the future, the new definitions, if they are expected to become widely used, must be integrated into this document for commonality across these types of applications. Of course, manufacturers are free to assign their own definitions to data parameters which are unique or proprietary to their products. They are, however, restricted to using the "Manufacturer Reserved" message header assignments in Parts 3 and 4 of this document when using these unique or proprietary data parameter definitions.

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 J1850—Class B Data Communication Network Interface

SAE J1979—E/E Diagnostic Test Modes

SAE J2190—Enhanced E/E Diagnostic Test Modes

2.1.2 ANSI PUBLICATION—Available from ANSI, 11 West 42nd Street, New York, NY 10036-8002.

ANSI/IEEE Std 754-1985, August 12, 1985—IEEE Standard for Binary Floating-Point Arithmetic

2.2 Related Publications—The following publications are provided for information purposes only and are not a required part of this document.

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

SAE J1213/1—Glossary of Vehicle Networks for Multiplex and Data Communication

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

2.3 Terms and Definitions

2.3.1 DATA [DATA FIELD]—Data and data field are used interchangeably in this document and they both refer to a field within a frame that may include bytes with parameters pertaining to the message and/or secondary ID and/or extended addresses and/or test modes which further defines a particular message content being exchanged over the network.

2.3.2 EXTENDED ADDRESS—The extended address is a means to allow a message to be addressed to a specific geographical location or zone of the vehicle, independent of any node's physical address.

2.3.3 FRAME—A frame is one complete transmission of information which may or may not include an In-Frame Response. The frame is enclosed by the start of frame and end of frame symbols. For Class B networks, each frame contains one and only one message (see "message" definition).

2.3.4 FRAME ID—The Frame ID is the header byte for the Single Byte Header format and the one byte form of the consolidated header format. The definition of the frame ID is found in SAE J2178, Part 3. This header byte defines the target and source and content of the frame.

2.3.5 FUNCTIONAL ADDRESSING—Functional addressing allows a message to be addressed or sent to one or more nodes on the network interested in that function. Functional addressing is intended for messages that may be of interest to more than a single node. For example, an exterior lamp "off" message could be sent to all nodes controlling the vehicle exterior lamps by using a functional address. The functional address consists of a primary ID and may include a secondary ID and may also include an extended address.

2.3.6 HEADER [HEADER FIELD]—The header (or header field, used interchangeably) is a one or three byte field within a frame which contains information about the message priority, message source and target addressing, message type, and in-frame response type.

2.3.7 IN-FRAME RESPONSE (IFR) TYPE—The IFR type identifies the form of the in-frame response which is expected within that message.

2.3.8 LOAD—The load command indicates the operation of directly replacing the current/existing value of a parameter with the parameter value(s) contained in the message.

2.3.9 MESSAGE—A message consists of all of the bytes of a frame excluding the delimiter symbols (SOF, EOD, EOF, NB).

2.3.10 MODIFY—The modify command indicates the operation of using the message data parameter value to change (e.g., increment, decrement, or toggle) the current/existing value.

2.3.11 PARAMETER—A parameter is the variable quantity included in some messages. The parameter value, scaling, offset, units, transfer function, etc., are unique to each particular message. (The assigned parameters are contained herein.)

2.3.12 PHYSICAL ADDRESSING—Physical addressing allows a message to be addressed to a specific node or to all nodes or to a non-existent, null node. The information in this message is only of relevance to a particular node, so the other nodes on the bus should ignore the message, except for the case of the "all nodes" address.

2.3.13 PRIMARY ID—The primary ID identifies the target for this functional message. This is the primary discriminator used to group functions into main categories.

2.3.14 PRIORITY—The priority describes the rank order and precedence of a message. Based upon the SAE J1850, Class B arbitration process, the message with the highest priority will win arbitration.

2.3.15 REPORT—A report indicates the transmission of parametric data values, based on: a change of state; a change of value; on a periodic rate basis; or as a response to a specific request.

2.3.16 REQUEST—A request is a command to, or a query for data, or action from another node on the network.

2.3.17 RESPONSE DATA—The response data is the information from a node on the network in response to a request from another node on the network. This may be an in-frame response or a report type of message.

2.3.18 SECONDARY ID—The secondary ID (along with the primary ID or Frame ID) identifies the functional target node for a message. The purpose of the secondary ID field within the frame is to further define the function or action being identified by the primary ID.

2.4 Abbreviations and Acronyms

A/C - Air Conditioning
ASC - ASCII Encoded SLOT
BCD - Binary Coded Decimal (BCD) SLOT
BMM - Bit Mapped with Mask SLOT
BMP - Bit Mapped without Mask SLOT
CRC - Cyclic Redundancy Check
CS - Checksum
DTC - Diagnostic Trouble Code
EOD - End of Data
EOF - End of Frame
ERR - Error Detection
HVAC - Heating, Ventilation, Air Conditioning
ID - Identifier
IFR - In-Frame Response
LSB - Least Significant Bit/Byte
MSB - Most Significant Bit/Byte
NB - Normalization Bit
PID - Parameter IDentification (number, NOT the primary ID, See Section 6)
PKT - Multiple Parameter Packet SLOT
PRN - Parameter Reference Number
SED - State Encoded SLOT
SFP - Signed Floating Point (Scientific Notation) SLOT
SLOT - Scaling, Limit, Offset, and Transfer Function (See Section 7)
SNM - 2's Complement Signed Numeric SLOT
SOF - Start of Frame
UNM - Unsigned Numeric SLOT
VIN - Vehicle Identification Number

3. *General Information*

3.1 Part 2 Overview—Section 4 provides a description of the parameter reference number (PRN) number groupings used for assigning PRN numbers to

individual parameters. Section 5 defines the formats used to define all standard parameters to be used in SAE J2178 messages. Section 6 defines the specific parameter assignments in terms of names, units, and scale factor reference. Section 7 defines the actual parameter specifications (SLOT), in terms of the length, bit resolution, range, scale factor details, etc. Section 8 describes the case of very long parameters which cannot be transmitted in a single message. Appendix A provides a numerical cross reference to assist in finding the correct name of a parameter if the parameter identification number is known. Appendix B is an alphabetical cross reference to assist in finding the correct parameter identification number if the parameter name is known.

The messages contain header fields and data fields, described in Part 1 of SAE J2178. The header field contains target, source, priority, and message type information, while the data field contains optional additional addressing and parametric information. This document defines the parametric information.

For some applications, it is desirable to include multiple parameters in a single message. The multiple parameter format is called a packet in this document. For example, some diagnostic messages consist of combinations of these parameters to improve information density or to insure simultaneous readings of different variables. A very limited set of these combinations are defined here as industry standards but individual manufacturers are free to use this form in manufacturer specific messages, as needed.

3.2 How To Use This Document—This part (Part 2 of SAE J2178) provides the definition of parameters which are commonly found, or could be expected in vehicle Electrical/Electronic Systems today. These parameters have been defined to allow messages on a Class B communication system to have consistent meaning between manufacturers and over time. The parameter definition consists of two parts, the "PRN" and the "SLOT." The "PRN" (Parameter Reference Number) is a number used to identify a specific parameter by name, unit of measure, and its associated "SLOT." The "SLOT" defines the mathematical characteristics of parameters in terms of its representation (Binary, Unsigned Numeric, ASCII, BCD, etc.), its scaling (1 Bit =), its limits and offsets, and its transfer function.

To find a parameter by name or PRN number, Appendices A and B provide cross references to the page of this document where the PRN can be found. The PRN numbers have also been grouped by subsystem to enable the reader to look for parameters if the name is not known.

If the parameter has not as yet been included in the list of PRNs, users can define new parameters in terms of the SLOTs which have been defined.

4. Parameter Reference Number (PRN) Structure—Parameter Reference Numbers (PRNs) are used to simplify documentation. They do not, in themselves, have particular significance. PRNs do allow simplification of reference, particularly for diagnostic purposes. To this end, a structure for PRN number assignments has been developed. The structure is described in the following paragraphs. Some of the PRN numbers are assigned or reserved for SAE definitions but the majority are reserved for individual motor vehicle manufacturers to coordinate and assign.

All PRN addresses are two bytes long, with the first byte identifying a grouping or classification reference (refer to Tables 1 and 2). The second byte is then a sequence number pointing to the specific parameter used (refer to Tables 4 through 19). There has not been any attempt made to group or commonize the meaning in the second byte. The specific assignments are found in Section 6. Note that all PRN addresses are listed as hexidecimal numbers throughout this document.

SAE J1979 refers to PID numbers which are a single byte reference number. The first 256 PRNs defined here (first byte = 00), are identical with the SAE J1979 PID definitions.

Figure 3 shows the basic structure of PRNs and Tables 1 and 2 show bit assignments and address ranges based on these assignments.

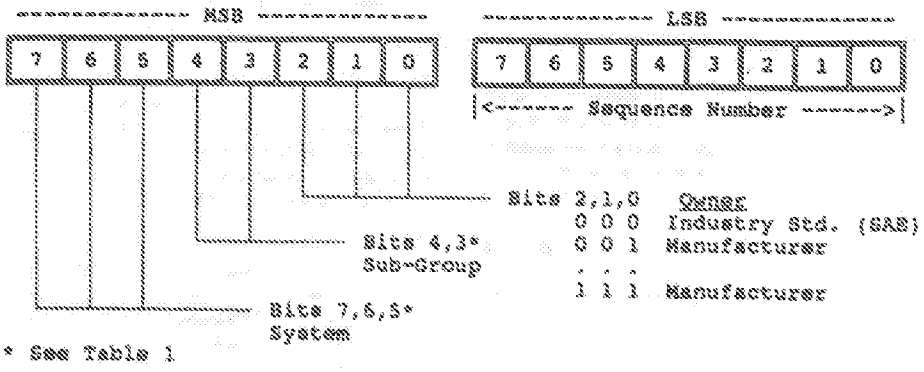


FIGURE 3—PRN STRUCTURE

5. Parameter Formats—Parameter values are represented in bit, byte, word, and multi-byte forms. The length of the parameter is uniquely associated with the message header and any included secondary ID field. These parameter definitions are referenced by one or more messages. The parameters allow a wide variety of variables, data definitions and representations to provide the ability to use this definition for all messages, even when the industry standard messages are not useful for particular applications.

5.1 Bit Mapped Parameters—The bit mapped parameters, that is, those which have only two logical values (for example: True/False), are handled in one of two ways. The "Q" bit described in Section 6 of Part 1 of SAE J2178, is used if there is only one bit of information. In many cases, however, the bit values are associated together and form byte groupings, generally around common functional characteristics. Bit mapped data are transmitted either with or without corresponding mask bytes as described as follows.

5.1.1 Bit Mapped Data Without Mask Byte(s)—In some cases, such as configuration identification, there is information which can be grouped as binary bits which represent whether, for example, a function or test is supported in a system. This form does not allow the bits to be supplied from different nodes in the network. If the bits potentially come from more than one node, the form with mask bytes described in 5.1.2, is used. The general form of the bit data bytes without mask is shown in Figure 4.

For these bit data cases, the bit names (that is: items) are somewhat different to emphasize the difference in format. These names are shown in Figure 5. If there is more than one byte of data of this form, the item numbers are incremented by one, sequentially, beginning at one from the MSB of the first byte.

For definition purposes, it is also possible to describe a single or multiple bit group which is smaller than a byte but which are combined into a byte or multiple bytes when the complete message is defined. This is a convenience used in this document to define some parameters. This definition notation applies equally to byte(s) with or without masks.

5.1.2 Bit Mapped Data With Mask Byte(s)—For bit mapped data value groups that may come from several nodes or may not be valid for an application, a special format has been defined. Figures 6 and 7 show the data byte formats used. The data format allows two options in the number of bits in a group: 8 or 16. Since the defined bits for such groupings may not always come from a single network node, the format includes mask bytes indicating if an individual bit is valid for this message or if it should be ignored. The mask bytes map directly to the data bits with which they are associated. Figures 8 and 9 show how these bits are mapped within each byte. Table 3 shows the bit value for the mask bits.

Page 713 of 1656 OMEGA EXHIBIT 2037

TABLE 1—PID Assignments

7 6 5	System	4 3	Subgroup	Address (hex)
0 0 0	Powertrain	0 0	J1979 Compatible	0000-07FF
		0 0	Reserved	0100-07FF
		0 1	Reserved	0800-0FFF
		1 0	Engine	1000-17FF
		1 1	Transmission	1800-1FFF
0 0 1	Chassis	0 0	Reserved	2000-27FF
		0 1	Brakes/Tires/Wheels	2800-2FFF
		1 0	Steering	3000-37FF
		1 1	Suspension	3800-3FFF
0 1 0	Body 1	0 0	Reserved	4000-47FF
		0 1	Reserved	4800-4FFF
		1 0	Reserved	5000-57FF
		1 1	Reserved	5800-5FFF
0 1 1	Body 2	0 0	Driver Info.	6000-67FF
		0 1	Reserved	6800-6FFF
		1 0	Lighting	7000-77FF
		1 1	Reserved	7800-7FFF
1 0 0	Body 3	0 0	Audio	8000-87FF
		0 1	Reserved	8800-8FFF
		1 0	Pers. Comm.	9000-97FF
		1 1	HVAC	9800-9FFF
1 0 1	Body 4	0 0	Convenience	A000-A7FF
		0 1	Reserved	A800-AFFF
		1 0	Reserved	B000-B7FF
		1 1	Reserved	B800-BFFF
1 1 0	Other 1	0 0	Security	C000-C7FF
		0 1	Reserved	C800-CFFF
		1 0	Reserved	D000-D7FF
		1 1	Reserved	D800-DFFF
1 1 1	Other 2	0 0	Config. Codes	E000-E7FF
		0 1	Reserved	E800-EFFF
		1 0	Tester/Diag.	F000-F7FF
		1 1	Miscellaneous	F800-FFFF

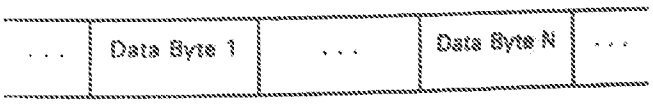


FIGURE 4—BIT DATA FIELD WITHOUT MASK FORMAT

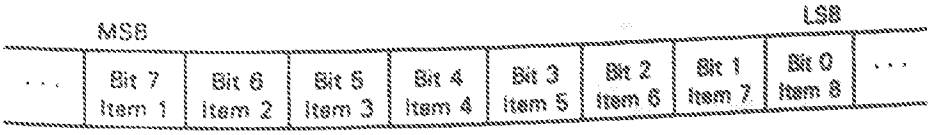


FIGURE 5—BITS WITHOUT MASK BYTE

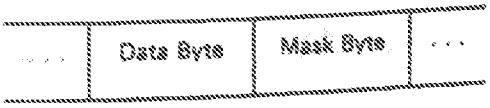


FIGURE 6—FORMAT FOR 8-BIT DATA WITH MASK

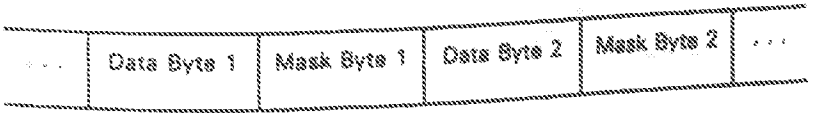


FIGURE 7—FORMAT FOR 16-BIT DATA WITH MASK

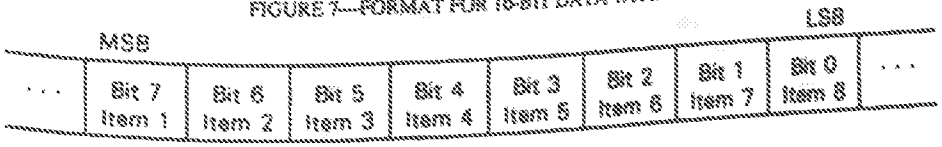


FIGURE 8—BIT MAPPED DATA BYTE

OMEGA EXHIBIT 2037

TABLE 9—SAE/MFG PRN RANGES

System	Subgroup	Address Map	Size
Powertrain	J1979 Compatible - SAE	0000 - 00FF	0.25K
	Reserved - MFG	0100 - 07FF	1.75K
	Reserved - SAE	0800 - 08FF	0.25K
	Reserved - MFG	0900 - 0FFF	1.75K
	Engine - SAE	1000 - 10FF	0.25K
	Engine - MFG	1100 - 17FF	1.75K
	Transmission - SAE	1800 - 18FF	0.25K
	Transmission - MFG	1900 - 1FFF	1.75K
Chassis	Reserved - SAE	2000 - 20FF	0.25K
	Reserved - MFG	2100 - 27FF	1.75K
	Brakes/Tires/Wheels - SAE	2800 - 28FF	0.25K
	Brakes/Tires/Wheels - MFG	2900 - 2FFF	1.75K
	Steering - SAE	3000 - 30FF	0.25K
	Steering - MFG	3100 - 37FF	1.75K
	Suspension - SAE	3800 - 38FF	0.25K
	Suspension - MFG	3900 - 3FFF	1.75K
Body 1	Reserved - SAE	4000 - 40FF	0.25K
	Reserved - MFG	4100 - 47FF	1.75K
	Reserved - SAE	4800 - 48FF	0.25K
	Reserved - MFG	4900 - 4FFF	1.75K
	Reserved - SAE	5000 - 50FF	0.25K
	Reserved - MFG	5100 - 57FF	1.75K
	Restraints - SAE	5800 - 5800	0.25K
	Restraints - MFG	5900 - 5FFF	1.75K
Body 2	Driver Information - SAE	6000 - 60FF	0.25K
	Driver Information - MFG	6100 - 67FF	1.75K
	Reserved - SAE	6800 - 68FF	0.25K
	Reserved - MFG	6900 - 6FFF	1.75K
	Lighting - SAE	7000 - 70FF	0.25K
	Lighting - MFG	7100 - 77FF	1.75K
	Reserved - SAE	7800 - 78FF	0.25K
	Reserved - MFG	7900 - 7FFF	1.75K
Body 3	Audio - SAE	8000 - 80FF	0.25K
	Audio - MFG	8100 - 87FF	1.75K
	Reserved - SAE	8800 - 88FF	0.25K
	Reserved - MFG	8900 - 8FFF	1.75K
	Personal Communications - SAE	9000 - 90FF	0.25K
	Personal Communications - MFG	9100 - 97FF	1.75K
	HVAC - SAE	9800 - 98FF	0.25K
	HVAC - MFG	9900 - 9FFF	1.75K
Body 4	Convenience - SAE	A000 - A0FF	0.25K
	Convenience - MFG	A100 - A7FF	1.75K
	Reserved - SAE	A800 - A8FF	0.25K
	Reserved - MFG	A900 - AFFF	1.75K
	Reserved - SAE	B000 - B0FF	0.25K
	Reserved - MFG	B100 - B7FF	1.75K
	Reserved - SAE	B800 - B8FF	0.25K
	Reserved - MFG	B900 - BFFF	1.75K
Other 1	Security - SAE	C000 - C0FF	0.25K
	Security - MFG	C100 - C7FF	1.75K
	Reserved - SAE	C800 - C8FF	0.25K
	Reserved - MFG	C900 - CFFF	1.75K
	Reserved - SAE	D000 - D0FF	0.25K
	Reserved - MFG	D100 - D7FF	1.75K
	Reserved - SAE	D800 - D8FF	0.25K
	Reserved - MFG	D900 - DFFF	1.75K
Other 2	Configuration Codes - SAE	E000 - E0FF	0.25K
	Configuration Codes - MFG	E100 - E7FF	1.75K
	Reserved - SAE	E800 - E8FF	0.25K
	Reserved - MFG	E900 - EFFF	1.75K
	Tester/Diagnostics - SAE	F000 - F0FF	0.25K
	Tester/Diagnostics - MFG	F100 - F7FF	1.75K
	Miscellaneous - SAE	F800 - F8FF	0.25K
	Miscellaneous - MFG	F900 - FFFF	1.75K

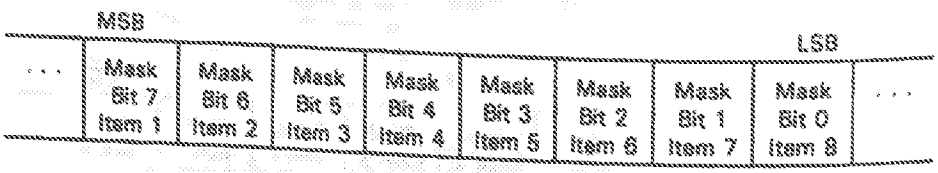


FIGURE 9—BIT MAPPED MASK BYTE

OMEGA EXHIBIT 2037

TABLE 8—MASK BIT ASSIGNMENT

Mask Bit	Bit Required Reading
0	Not A Valid Bit
1	Valid Bit

5.1.3 Bit Values—The general form of binary data is that 1 = true and 0 = false. One bit can carry a wide variety of interpretations, depending on the subject that it describes.

5.2 Byte (8 Bit) Parameters—Data parameters which can be expressed in 8 bits or less are expressed in a byte format. Byte parameters are the most common format. Figure 10 shows this format.

5.3 Word (16 Bit) Parameters—Data parameters which can be expressed in 9 to 16 bits are expressed in word format with the most significant byte transmitted first (high byte/low byte). Figure 11 shows this format.

5.4 Multi-Byte (>16 Bit) Parameters—Data parameters which can be expressed in more than 16 bits are expressed in multi-byte format with the most significant byte transmitted first (highest byte /.../ lowest byte). Figure 12 shows this format.

5.5 Multiple Parameter Packets—It is often useful to group parameters together into a packet to increase the information density of messages. For example, sending a fluid level and maximum capacity value in the same message, or a packet of single bit(s) or multiple bit definitions that may be smaller than a full byte, can be combined in this way. Parameter packets will be defined in this document in the same way as any other parameter, having a packet PRN number and SLOT reference assignment. If bit mapped parameters are included in a packet, the bit mapped byte(s) and the associated mask byte(s) are grouped together as a set representing a parameter. Thus, the data bytes and mask bytes for each parameter are together within the packet. Note that packets may be made of other packets, but each will be uniquely defined by combining each subpart into a message. Figure 13 shows the general form of a parameter packet.

A few examples, such as some of the SAE J1979 compatible PRN definitions in Section 6 will make this format clear.

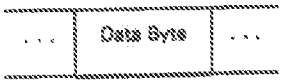


FIGURE 10—BYTE PARAMETERS

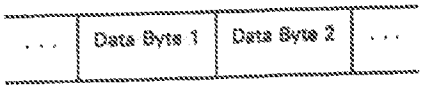


FIGURE 11—WORD PARAMETERS

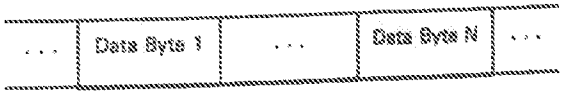


FIGURE 12—MULTI-BYTE PARAMETERS

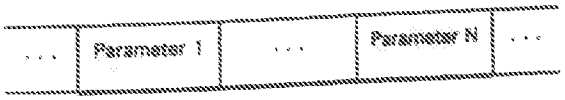


FIGURE 13—MULTIPLE PARAMETER PACKETS

6. *Specific Parameter (PRN) Assignments*—This section defines industry standard parameters used in messages found in parts 3 and 4. These parameters have been listed in random order based on when they were defined. Note that any PRN address in the SAE range that is not currently defined is reserved for SAE use. Cross references are provided in Appendices A and B of this part of SAE J2178 to assist the reader in finding the specific definition for each parameter.

6.1 Specific Parameters—The following definitions include the Parameter Reference Number (PRN), parameter name, units of measure, and associated SLOT number. The SLOT number is a reference to the Scaling, Limit, Offset, and Transfer function (SLOT) definition found in Section 7 as follows. The SLOT reference numbers have a format of: F-N-#, where F is a three-letter mnemonic indicating the format code type (see Section 7), N is the number of bits in the parameter, and # is the sequence number for that type of

SLOT. There is no relationship between sequence numbers for different format codes or number of bytes. Note that the sequence number is randomly assigned. Decimal sequence numbers of 1000 and above are available for manufacturers to assign. All SAE-assigned sequence numbers will be in the range from 1 to 999 exclusively and are not to be used by manufacturers. The sequence number ZERO (0) has the special purpose of a fill sequence which is used in packet definitions. The ZERO sequence number is all zeros, for the number of bits specified. The Parameter Reference Numbers (PRNs) are the index reference used by the message definitions found in Parts 3 and 4 of this document. The specific parameters are grouped as follows:

- Table 4 - SAE J1979 Compatible PRN Assignments
- Table 5 - Engine PRN Assignments
- Table 6 - Transmission PRN Assignments
- Table 7 - Brakes/Tires/Wheels PRN Assignments
- Table 8 - Steering PRN Assignments
- Table 9 - Suspension PRN Assignments
- Table 10 - Restraints PRN Assignments
- Table 11 - Driver Information PRN Assignments
- Table 12 - Lighting PRN Assignments
- Table 13 - Audio PRN Assignments
- Table 14 - Personal Communication PRN Assignments
- Table 15 - HVAC PRN Assignments
- Table 16 - Convenience PRN Assignments
- Table 17 - Security PRN Assignments
- Table 18 - Configuration Codes PRN Assignments
- Table 19 - Tester/Diagnostics PRN Assignments
- Table 20 - Miscellaneous PRN Assignments

TABLE 4--SAE J1979 COMPATIBLE PRN ASSIGNMENTS
(PRNs 0000 - 00FF)

PRN	Parameter Name	Resolution (1 Bit =)	Units Of Measure	Stat.# (F-N-#)
0000	PIDs Supported (01h - 20h)	-	Bit Mapped	BMP-32-1
0001	Number of Emission-Related Trouble Codes & MIL Status	-	Packetized	PKT-32-1
0002	Trouble Code That Caused Freeze Frame Storage	-	Packetized	PKT-16-1
0003	Fuel System Status	-	Packetized	PKT-16-2
0004	Calculated Load Value	100/255	% Full Load	UNM-08-51
0005	Engine Coolant Temperature	1	Degrees Centigrade	UNM-08-102
0006	Short Term Fuel Trim - Bank 1	100/128	% Enrichment	UNM-08-52
0007	Long Term Fuel Trim - Bank 1	100/128	% Enrichment	UNM-08-52
0008	Short Term Fuel Trim - Bank 2	100/128	% Enrichment	UNM-08-52
0009	Long Term Fuel Trim - Bank 2	100/128	% Enrichment	UNM-08-52
000A	Fuel Pressure (Gage)	3	kPaG	UNM-08-131
000B	Intake Manifold Absolute Pressure	1	kPaA	UNM-08-101
000C	Engine RPM - High Resolution	1/4	RPM	UNM-16-11
000D	Vehicle Speed - Low Resolution - Metric	1	km/h	UNM-08-101
000E	Ignition Timing Advance (#1)	1/2	Degrees before TDC	UNM-08-72
000F	Intake Air Temperature	1	Degrees Centigrade	UNM-08-102
0010	Air Flow Rate from MAF	1/100	grams/sec	UNM-16-11
0011	Absolute Throttle #1 Position	100/255	% Full Throttle	UNM-08-81
0012	Commanded Secondary Air	-	Bit Mapped	BMP-08-5
0013	Oxygen Sensor Location	-	Bit Mapped	BMP-08-6
0014	Oxygen Sensor - BANK 1 - Sensor 1	-	Packetized	PKT-16-3
0015	Oxygen Sensor - BANK 1 - Sensor 2	-	Packetized	PKT-16-3
0016	Oxygen Sensor - BANK 1 - Sensor 3	-	Packetized	PKT-16-3
0017	Oxygen Sensor - BANK 1 - Sensor 4	-	Packetized	PKT-16-3
0018	Oxygen Sensor - BANK 2 - Sensor 1	-	Packetized	PKT-16-3
0019	Oxygen Sensor - BANK 2 - Sensor 2	-	Packetized	PKT-16-3
001A	Oxygen Sensor - BANK 2 - Sensor 3	-	Packetized	PKT-16-3
001B	Oxygen Sensor - BANK 2 - Sensor 4	-	Packetized	PKT-16-3
001C	Reserved SAE	-	-	-
001D	Reserved SAE	-	-	-
001E	Reserved SAE	-	-	-
001F	Reserved SAE	-	-	-
0020	PIDs Supported (21h - 40h)	-	Bit Mapped	BMP-32-2
0021-003F	Reserved SAE	-	-	-
0040	PIDs Supported (41h - 60h)	-	Bit Mapped	BMP-32-3
0041-00FF	Reserved SAE	-	-	-

TABLE 5---ENGINE PIN ASSIGNMENTS
(PINs 1000 - 1055)

PIN	PARAMETER NAME	RESOLUTION (1 bit =)	UNITS OF MEASURE	SLOT # (F-M-S)
1000	MIL Status	-	Bit Mapped	BMP-01-1
1001	Number of Emissions Related DTCs	1	Quantity	UNM-07-1
1002	Continuous Evaluation Supported	-	Bit Mapped	BMP-08-1
1003	Trip Evaluation Supported	-	Bit Mapped	BMP-08-2
1004	Trip Evaluation Complete	-	Bit Mapped	BMP-08-3
1005	Sub-System Category of DTC	-	State Encoded	SED-08-1
1006	Most Significant Digit of DTC	-	State Encoded	SED-08-2
1007	Lower 3 Digits of DTC	-	BCD	BCD-12-1
1008	Fuel System Status - Bank 1	-	Bit Mapped	BMP-08-4
1009	Fuel System Status - Bank 2	-	Bit Mapped	BMP-08-4
100A	Oxygen Sensor Voltage	1/200	volts	UNM-08-11
100B	Short Term Fuel Trim	100/128	% Enrichment	UNM-08-82
100D	Most Significant Digit of VIN Number	-	ASCII	ASC-08-01
100E	A/C Clutch Load	25	Watts	UNM-08-168
1015	Injector On Time	2048	microseconds	UNM-08-031
1019	Crankshaft Torque - Absolute	4	N.m Torque	UNM-08-141
1020	Crankshaft Torque - Percent	100/255	% Maximum Torque	UNM-08-81
1021	Engine Boost	100/255	% Full Boost	UNM-08-81
1022	Engine RPM - Low Resolution	32	RPM	UNM-08-171
1023	Engine Idle RPM	16	RPM	UNM-08-181
1024	Engine Revolutions	8	Quantity	UNM-08-121
1025	Barometric Pressure	1	kPaA	UNM-08-161
1026	Engine Coolant Level - Percent	1/2	% Full	UNM-08-71
1027	Engine Coolant Level - Volume	1/10	liters	UNM-08-41
1028	Engine Coolant Capacity	1/10	liters	UNM-08-41
1029	Engine Coolant Pressure	4	kPaG	UNM-08-141
102A	Engine Coolant Fan #1 Speed	100/255	% Full On	UNM-08-81
102B	Engine Oil Temperature	1	Degrees Centigrade	UNM-08-102
102C	Engine Oil Level - Percent	1/2	% Full	UNM-08-71
102D	Engine Oil Level - Volume	1/10	liters	UNM-08-41
102E	Engine Oil Capacity	1/10	liters	UNM-08-41
102F	Engine Oil Pressure	4	kPaG	UNM-08-141
1030	Engine Oil Remaining Life	100/255	% Remaining Life	UNM-08-81
1031	Hydraulic Fan Speed	100/255	% Full On	UNM-08-81
1032	Methanol Content	100/255	% Methanol	UNM-08-81
1033	Maximum Crankshaft Torque	4	N.m Torque	UNM-08-141
1034	Accelerator Pedal Position	100/255	% Pressed Down	UNM-08-81
1035	Absolute Throttle #2 Position	100/255	% Full Throttle	UNM-08-81
1036	Absolute Throttle #3 Position	100/255	% Full Throttle	UNM-08-81
1037	Bank #1 - Converter #1 Temperature	8	Degrees Centigrade	UNM-08-151
1038	Bank #1 - Converter #2 Temperature	8	Degrees Centigrade	UNM-08-151
1039	Bank #2 - Converter #1 Temperature	8	Degrees Centigrade	UNM-08-151
103A	Bank #2 - Converter #2 Temperature	8	Degrees Centigrade	UNM-08-151
103B	Engine Coolant #2 Fan Speed	100/255	% Full On	UNM-08-81
103C	Engine Coolant Temperature - Low Range	1	Degrees Centigrade	UNM-08-104
103D	Engine Coolant Remaining Life	100/255	% Remaining Life	UNM-08-81
103F	Engine Oil Viscosity	1/10	Centistokes (cSt)	UNM-08-61
1040	Number of Engine Cylinders	1	Quantity	UNM-08-101
1041	Number of Valves per Cylinder	1	Quantity	UNM-08-101
1043	Engine Displacement	1/10	liters	UNM-08-41
1044	Fuel Temperature	1	Degrees Centigrade	UNM-08-102
1047	Ignition Switch Position	-	State Encoded	SED-08-5
1048	Engine Redline - Low Resolution	32	RPM	UNM-08-171
1049	Engine Redline - High Resolution	1/4	RPM	UNM-16-81

OMEGA EXHIBIT 2037

TABLE 6---TRANSMISSION PRN ASSIGNMENTS
(PRNs 1800 - 187F)

PRN	Parameter Name	Resolution (1 Bit =)	Units Of Measure	Slot 6 (F-N-6)
1801	Transmission Fluid Level - Percent	1/2	% Full	UNM-08-71
1802	Transmission Fluid Level - Volume	1/10	liters	UNM-08-41
1803	Transmission Fluid Capacity	1/10	liters	UNM-08-41
1804	Transmission Oil Life	100/255	% Remaining Life	UNM-08-81
1805	Transmission Gear & Lockup Status	-	Packaged	PKT-08-1
1806	Transmission Range Actual (PRNDL)	-	State Encoded	SED-08-4
1807	Transmission Lockup Status	-	State Encoded	SED-02-3
1808	Transmission Actual Gear	-	State Encoded	SED-08-1
1809	Transmission Range Selected (PRNDL)	-	State Encoded	SED-08-4
180A	Transmission Transfer Case (4WD)	-	State Encoded	SED-08-6
180B	Transmission Fluid Temperature	1	Degrees Centigrade	UNM-08-102
180C	Transmission Fluid Pressure	8	kPaG	UNM-08-151
180D	Transmission Commanded Gear	-	State Encoded	SED-08-4
180E	Transmission Actual Gear	-	State Encoded	SED-08-4

TABLE 7---BRAKES/TIRES/WHEELS PRN ASSIGNMENTS
(PRNs 2800 - 285F)

PRN	Parameter Name	Resolution (1 Bit =)	Units Of Measure	Slot 6 (F-N-6)
2801	Wheel Speed - Low Resolution	1	km/h	UNM-08-101
2802	Wheel Speed - High Resolution	1/128	km/h	UNM-18-5
2806	Wheel Slip	1/255	Dimensionless	UNM-08-8
2819	Hydraulic Brake Fluid Supply Pump Pressure	32	kPaG	UNM-08-171
281A	Hydraulic Brake Fluid Temperature	1	Degrees Centigrade	UNM-08-102
281B	Hydraulic Brake Fluid Recirculation Pump Pressure	1	kPaG	UNM-08-101
2821	Wheel Rate		SAE Reserved	SAE Reserved
2829	Wheel Angular Velocity		SAE Reserved	SAE Reserved
2831	Wheel Angular Acceleration		SAE Reserved	SAE Reserved
2839	Wheel Load	100/255	% Full Load	UNM-08-81
2841	Brake Fluid Level - Percent	1/2	% Full	UNM-08-71
2842	Brake Fluid Level - Volume	1/100	liters	UNM-08-15
2843	Brake Fluid Remaining Life	100/255	% Remaining Life	UNM-08-81
2844	Brake Fluid Capacity	1/100	liters	UNM-08-15
2849	Tire Temperature	1	Degrees Centigrade	UNM-08-102
2851	Tire Pressure	4	kPaG	UNM-08-141
2859	Tire Type		SAE Reserved	SAE Reserved
2861	Tire Tread Wear Level	100/255	% tread remaining	UNM-08-81

TABLE 8---STEERING PRN ASSIGNMENTS
(PRNs 3000 - 305F)

PRN	Parameter Name	Resolution (1 Bit =)	Units Of Measure	Slot 6 (F-N-6)
3001	Steering Wheel Angle	6	Degrees CW from center	SNM-08-61
3005	Power Steering Fluid Temperature	1	Degrees Centigrade	UNM-08-102
3006	Power Steering Fluid Pressure	100	kPaG	UNM-08-185
3007	Power Steering Fluid Level - Percent	1/2	% Full	UNM-08-71
3008	Power Steering Fluid Level - Volume	1/100	liters	UNM-08-15
3009	Power Steering Fluid Remaining Life	100/255	% Remaining Life	UNM-08-81
300B	Power Steering Fluid Capacity	1/100	liters	UNM-08-15
300C	Steering Wheel Rate	1	RPM	UNM-08-101
300D	Steering Wheel Torque	1	N.m Torque	UNM-08-101
300E	Wheel Steer Angle	1/2	Degrees CW from Center	SNM-08-11

TABLE 9—SUSPENSION PRN ASSIGNMENTS
(PRNs 3800 - 38FF)

PRN	Parameter Name	Resolution (1 Bit =)	Units Of Measure	SPN/S (PGN)
3801	Lateral Acceleration		SAE Reserved	SAE Reserved
3802	Longitudinal Acceleration		SAE Reserved	SAE Reserved
3803	Yaw Acceleration		SAE Reserved	SAE Reserved
3804	Suspension Ride Setting	100/255	% Stiff Setting	UNM-08-61
3805	Suspension Fluid Temperature	1	Degrees Centigrade	UNM-08-102
3806	Suspension Fluid Pressure	100	kPa/3	UNM-08-103
3807	Suspension Fluid Level - Percent	1/2	% Full	UNM-08-71
3808	Suspension Fluid Level - Volume	1/32	liters	UNM-08-62
3809	Suspension Fluid Remaining Life	100/255	% Remaining Life	UNM-08-61
380A	Suspension Fluid Capacity	1/32	liters	UNM-08-63
380B	Vehicle Lateral Velocity		SAE Reserved	SAE Reserved
380C	Vehicle Longitudinal Velocity		SAE Reserved	SAE Reserved
380D	Vehicle Yaw Velocity		SAE Reserved	SAE Reserved

TABLE 10—RESTRAINTS PRN ASSIGNMENTS
(PRNs 5800 - 58FF)

PRN	Parameter Name	Resolution (1 Bit =)	Units Of Measure	SPN/S (PGN)
5801	Shoulder Belt Position	1	Unscaled A/D Counts	UNM-08-101

TABLE 11—DRIVER INFORMATION PRN ASSIGNMENTS
(PRNs 6000 - 60FF)

PRN	Parameter Name	Resolution (1 Bit =)	Units Of Measure	SPN/S (PGN)
6001	Vehicle Speed - High Resolution - Metric	1/128	km/h	UNM-16-5
6002	Vehicle Speed - High Resolution - English	1/128	mph	UNM-16-6
6003	Compass Direction	2/3	Degrees CW from North	UNM-08-81
6004	Odometer - Vehicle - Metric	1/8	kilometers	UNM-08-31
6005	Fuel Level - Percent	100/255	% Full	UNM-08-61
6006	Fuel Level - Volume	1/100	liters	UNM-16-11
6007	Fuel Capacity	1/100	liters	UNM-16-15
6008	Battery Voltage - Low Resolution	1/16	volts	UNM-08-32
6009	Battery Temperature	1	Degrees Centigrade	UNM-08-102
600C	Electrical Energy Used	1	kWh/h	UNM-08-101
600D	Date (Day/DD MM/YY)	-	Packaded	PKT-02-0
600E	Year (YY)	-	BCD	BCD-08-1
600F	Year (Yr)	1	year	UNM-08-106
6010	Month (Mn)	-	Bits Encoded	BED-04-2
6011	Month (MM)	-	BCD	BCD-08-1
6012	Day of Week (Dwk)	-	Bits Encoded	BED-04-1
6013	Day of Week (Dwy)	-	Bits Encoded	BED-08-2
6014	Day of Month (Dm)	-	Bits Encoded	BED-08-3
6015	Day of Month (DD)	-	Bits Encoded	BED-08-1
6016	Time of Day (hh:MM:SS)	-	BCD	PKT-04-1
6017	Hours (hh)	-	Packaded	BCD-08-1
6018	Minutes (MM)	-	BCD	BCD-08-1
6019	Seconds (SS)	-	BCD	BCD-08-1
601A	Battery Voltage - High Resolution	1/128	volts	UNM-16-6
601B	Distance Traveled - English	1/8000	miles	UNM-08-1
601C	Fuel Used - Metric	1/64	liters	UNM-16-9
601D	Distance To Empty - English	1/16	miles	UNM-16-61
601E	Vehicle Speed - Low Resolution - English	1	MPH	UNM-08-101
601F	Hours (hr) - 0 to 23 numeric	1	hour	UNM-08-101
6020	Average Fuel Economy - Low Resolution - Metric	1	liters/100 kilometers/MM-08-101	
6021	Average Fuel Economy - Low Resolution - English	1	MPG	UNM-08-101
6022	Elapsed Time - Seconds	1	Seconds	UNM-08-101
6023	Date (Day/dd/ Dm)	-	Packaded	PKT-16-0

Continued

TABLE 11--DRIVER INFORMATION PRN ASSIGNMENTS
(PRNs 8000 - 80FF) (CONTINUED)

PRN	Parameter Name	Resolution (1 Bit =)	Units Of Measure	Std.# (F-N-#)
8024	Elapsed Time - Minutes	1	Minutes	UNM-08-101
8025	Accumulated Ignition On Time	-	Packeted	PKT-24-2
8026	Fuel Used - English	1/64	gallons	UNM-16-6
8027	Distance To Empty - Metric	1/10	kilometers	UNM-16-21
8028	Average Fuel Economy - High Resolution - Metric	1/10	liters/100 kilometersUNM-16-21	
8029	Average Fuel Economy - High Resolution - English	1/10	MPG	UNM-16-21
802A	Elapsed Time - Hours	1	Hours	UNM-08-101
802B	Display Brightness	100/255	% Full On	UNM-08-61
802C	Ignition Off Duration	1	Minutes	UNM-08-101
802D	Outside Air Temperature - High Resolution	1/256	Degrees CentigradeUNM-16-3	
802E	Outside Air Temperature Display	1/2	Degrees Centigrade	UNM-08-73
802F	Minutes (Mn) 0 - 59 numeric	1	minute	UNM-08-101
8030	Time (Hr:Mn)	-	Packeted	PKT-18-6
8031	Odometer - Vehicle - High Resolution - English	1/8000	miles	UNM-32-11
8032	Odometer - Trip - High Resolution - English	128/8000	miles	UNM-24-21
8033	Odometer - Vehicle - Low Resolution - English	1/10	miles	UNM-24-11
8034	Odometer - Trip - Low Resolution - English	1/10	miles	UNM-16-21
8035	Charging Voltage - Low Resolution	1/16	volts	UNM-08-32
8036	Charging Voltage - High Resolution	1/128	volts	UNM-16-5
8037	Charging Current	1	amps	UNM-08-101
8038	Battery Current	1	amps	SNM-08-21
8039	Odometer - Trip - Metric	1/64	kilometers	UNM-24-41
803A	Instantaneous Fuel Economy - Low Resolution - Metric	1	liters/100 kilometers	UNM-08-101
803B	Fuel Used - Percent	100/255	% Used	UNM-08-61
803C	Fuel Used - Volume	1/100	liters	UNM-16-11
803D	Audible Signal Volume	100/255	% Full Volume	UNM-08-61
803E	Audible Signal Type		SAE Reserved	SAE Reserved
803F	Instantaneous Fuel Economy - High Resolution - Metric	1/10	liters/100 kilometers	UNM-16-21
8040	Instantaneous Fuel Economy - Low Resolution - English	1	MPG	UNM-08-101
8041	Instantaneous Fuel Economy - High Resolution - English	1/10	MPGUNM-16-21	
8042	Seconds (Sc) 0 - 59 numeric	1	seconds	UNM-08-101
8047	Alarm Time (HH:MM:SS)	-	Packeted	PKT-24-1
8048	Elapsed Years	1	years	UNM-08-101
804A	Elapsed Months	1	months	UNM-08-101
804B	Elapsed Days	1	days	UNM-08-101

TABLE 12--LIGHTING PRN ASSIGNMENTS
(PRNs 7000 - 70FF)

PRN	Parameter Name	Resolution (1 Bit =)	Units Of Measure	Std.# (F-N-#)

TABLE 13--AUDIO PRN ASSIGNMENTS
(PRNs 8000 - 80FF)

PRN	Parameter Name	Resolution (1 Bit =)	Units Of Measure	Std.# (F-N-#)

TABLE 14--PERSONAL COMMUNICATION PRN ASSIGNMENTS
(PRNs 8000 - 80FF)

PRN	Parameter Name	Resolution (1 Bit =)	Units Of Measure	Std.# (F-N-#)

TABLE 15--HVAC PRN ASSIGNMENTS
(PRNs 9800 - 98FF)

PRN	Parameter Name	Resolution (1 Bit =)	Units Of Measure	SAE J (PID-6)
9801	HVAC Fan Speed	100/255	% Full On	UNM-08-61
9803	HVAC Door Position	100/255	% Open	UNM-08-61
9804	Electric Defrost Temperature	1	Degrees Centigrade	UNM-08-102
9808	HVAC High Side Fluid Temperature	1	Degrees Centigrade	UNM-08-102
9809	HVAC Low-Side Fluid Temperature	1	Degrees Centigrade	UNM-08-102
980A	HVAC Low-Side Pressure	8/2	kPaG	UNM-08-103
980B	HVAC Fluid Charge - % Full Charge	100/255	% Full	UNM-08-61
980C	HVAC Fluid Charge - Absolute Weight	10	grams	UNM-08-155
980D	HVAC Fluid Charge Remaining Life	100/255	% Remaining Life	UNM-08-61
980E	HVAC Fluid Charge Capacity	10	grams	UNM-08-155
9810	HVAC Intake Temperature	1/2	Degrees Centigrade	UNM-08-73
9813	HVAC High Side Pressure	1/4	kPaG	UNM-08-159
9815	Interior Humidity Level	100/255	% Relative Humidity	UNM-08-61
9816	Interior Air Filter Remaining Life	100/255	% Remaining Life	UNM-08-61
9817	Heat Load Sensor	1/2	mV/count	UNM-08-71
9820	Interior Set Temperature	1/2	Degrees Centigrade	UNM-08-73
9830	HVAC Zone Temperature	1/2	Degrees Centigrade	UNM-08-73

TABLE 16--CONVENIENCE PRN ASSIGNMENTS
(PRNs A000 - A0FF)

PRN	Parameter Name	Resolution (1 Bit =)	Units Of Measure	SAE J (PID-6)
A001	Seat Temperature	1/2	Degrees Centigrade	UNM-08-76
A003	Wiper Mode	-	State Encoded	SED-08-1
A004	Wiper Delay	1/4	seconds	UNM-08-61
A006	Washer Fluid Temperature	1	Degrees Centigrade	UNM-08-102
A007	Washer Fluid Pressure	4	kPaG	UNM-08-161
A008	Washer Fluid Level - Percent	100/255	% Full	UNM-08-61
A009	Washer Fluid Level - Volume	1/10	liters	UNM-08-41
A00A	Washer Fluid Capacity	1/10	liters	UNM-08-41
A00C	Mirror Dimming Level	100/255	% Full Dim	UNM-08-61
A00D	Mirror Horizontal Position	1	Uncoded A/D Counts	UNM-08-101
A00E	Mirror Vertical Position	1	Uncoded A/D Counts	UNM-08-101
A00F	Window Position	1	Uncoded A/D Counts	UNM-08-101
A010	Door Lock Cylinder State	-	State Encoded	SED-08-7
A011	Steering Column Horizontal Position	1	Uncoded A/D Counts	UNM-08-101
A012	Steering Column Vertical Position	1	Uncoded A/D Counts	UNM-08-101
A014	Autolamp Off Delay Time	1	Seconds	UNM-08-101
A015	Vehicle Speed Setting - Low Resolution - Metric	1	km/h	UNM-18-6
A016	Vehicle Speed Setting - High Resolution - Metric	1/128	km/h	UNM-08-101
A017	Vehicle Speed Setting - Low Resolution - English	1	MPH	UNM-18-6
A018	Vehicle Speed Setting - High Resolution - English	1/128	MPH	UNM-18-6

TABLE 17--SECURITY PRN ASSIGNMENTS
(PRNs C000 - C0FF)

PRN	Parameter Name	Resolution (1 Bit =)	Units Of Measure	SAE J (PID-6)
C001	Remote Transmitter ID	1	ID Number	UNM-08-101

TABLE 18--CONFIGURATION CODES PRN ASSIGNMENTS
(PRNs E000 - E0FF)

PRN	Parameter Name	Resolution (1 Bit =)	Units Of Measure	SAE J (PID-6)
E021	Vehicle Id Number (VIN) #1	-	VIN character 1	PCT-30-2
E022	Vehicle Id Number (VIN) #2	-	VIN characters 2 - 5	ASC-32-1
E023	Vehicle Id Number (VIN) #3	-	VIN characters 6 - 9	ASC-32-1
E024	Vehicle Id Number (VIN) #4	-	VIN characters 10 - 13	ASC-32-1
E025	Vehicle Id Number (VIN) #5	-	VIN characters 14 - 17	ASC-32-1
E026	Vehicle Id Number (VIN) #6 (reserved for future use)	-	Reserved - SAE	Reserved - SAE
E027	Vehicle Id Number (VIN) #7 (reserved for future use)	-	Reserved - SAE	Reserved - SAE

TABLE 19---TESTER/DIAGNOSTICS PRN ASSIGNMENTS
(PRNs F800 - F8FF)

PRN	Parameter Name	Resolution (1 Bit =)	Units Of Measure	Slot # (F-N-#)

TABLE 20---MISCELLANEOUS PRN ASSIGNMENTS
(PRNs F800 - F8FF)

PRN	Parameter Name	Resolution (1 Bit =)	Units Of Measure	Slot # (F-N-#)
F801	One Byte Zero Fill	0	Zero	UNM-08-0
F802	Two Byte Zero Fill	0	Zero	UNM-16-0
F803	Three Byte Zero Fill	0	Zero	UNM-24-0
F804	Four Byte Zero Fill	0	Zero	UNM-32-0
F805	Five Byte Zero Fill	0	Zero	UNM-40-0
F806	Six Byte Zero Fill	0	Zero	UNM-48-0
F807	Seven Byte Zero Fill	0	Zero	UNM-56-0

7. Scaling, Limit, Offset, and Transfer Function (SLOT) Definitions---This section defines the parameter scaling, limit(s), offset value, and transfer function for bit, byte, or larger variables. These SLOT definitions have been grouped together to avoid duplication in this document and to offer a common list of definitions for use in assigning new parameter definitions. The wide range of these definitions are expected to cover a large number of applications, and should be used for most new definitions as well. Each of these definitions has been assigned a SLOT number for reference purposes but are formatted to include a three-letter mnemonic representing the format, the parameter length in bits, followed by a random sequence number.

The transfer function is shown in two forms to allow use in implementing messages in modules and in interpreting messages found on a network. The two forms are identical but are solved for each of the two variables. The transfer function defines the relationship between computer units (N) in decimal, and engineering units (E) of the data.

The format of the SLOT, identified by the three-letter mnemonic, indicates the category of bit representation. These formats include:

- Multiple Parameter Packeted	PKT
- Bit Mapped with Mask	BMM
- Bit Mapped without Mask	BMP
- Unsigned Numeric	UNM
- 2's Complement Signed Numeric	SNM
- State Encoded	SED
- ASCII Encoded	ASC
- Binary Coded Decimal (BCD)	BCD
- Signed Floating Point (Scientific Notation)	SFP

These formats for each are described in the following paragraphs.

7.1 Multiple Parameter Packeted (PKT) SLOTs---The multiple parameter packet is used to define PRNs which refer to more than one parameter as a group that are related. By grouping multiple parameters, the network bandwidth can be improved, if the groupings are done such that the individual parameters need to be associated such that the each need to be transmitted together. These packets are defined as a sequence of other PRN numbers, in the order that they appear in the message (MSB first). In some cases, a PRN may be assigned to fill bits or bytes with zeros. Each zero fill PRN is an unsigned numeric SLOT with zero as the sequence number.

7.1.1 MULTIPLE PARAMETER PACKETED ASSIGNMENTS

PKT-08-1 Transmission Gear & Lockup Status (PRN 1805)

MSB	PRN 1807	Transmission Lockup Status	2 bits
LSB	PRN 1808	Transmission Gear Engaged	6 bits

PKT-16-1 Trouble Code That Caused Freeze Frame Storage (PRN 0002)

MSB	PRN 1005	Sub-System Category	2 bits
	PRN 1006	MSB of Trouble Code	2 bits
LSB	PRN 1007	Lower Bytes of Trouble Code - BCD	12 bits

PKT-16-2 Fuel System Status (PRN 0003)

MSB	PRN 1008	Fuel System Status - Bank 1	8 bits
LSB	PRN 1009	Fuel System Status - Bank 2	8 bits

PKT-16-3 Oxygen BANK 1, 2 - Sensor 1, 2, 3, or 4 (PRN 0014 - 001B)

MSB	PRN 100A	Oxygen Sensor Voltage	8 bits
LSB	PRN 100B	Short Term Fuel Trim	8 bits

PKT-16-5 Time (Hr:Mn) (PRN 6030)

MSB	PRN 601F	Hours (0 - 23)	8 bits
LSB	PRN 602F	Minutes (0 - 59)	8 bits

PKT-16-6 Date (Dw,/Mn:Dm) (PRN 6023)

MSB	PRN 6012	Day of Week (1 - 7)	4 bits
	PRN 6010	Month (1 - 12)	4 bits
LSB	PRN 6014	Day of Month (1 - 31)	8 bits

PKT-24-1 Time of Day (HH:MM:SS) (PRN 6016)

MSB	PRN 6017	Hours (HH) - BCD	8 bits
	PRN 6018	Minutes (MM) - BCD	8 bits
LSB	PRN 6019	Seconds (SS) - BCD	8 bits

PKT-24-2 Accumulated Ignition On Time (PRN 6025)

MSB	PRN 602A	Elapsed Time-Hours (0-99)	8 bits
	PRN 6024	Elapsed Time-Minutes (0-59)	8 bits
LSB	PRN 6022	Elapsed Time-Seconds (0-59)	8 bits

PKT-32-1 Number of Emission-Related Trouble Codes & MIL Status (PRN 0001)

MSB	PRN 1000	MIL Status	1 bit
	PRN 1001	Number of Emission-Related Trouble Codes	7 bits
	PRN 1002	Continuous Evaluation Supported	8 bits
	PRN 1003	Trip Evaluation Supported	8 bits
LSB	PRN 1004	Trip Evaluation Complete	8 bits

PKT-32-2 Vehicle Id Number (VIN) #1 (PRN 0021)

MSB	PRN F803	Three Byte - Zero Fill	24 bits
LSB	PRN 100D	MSB of VIN Number	8 bits

PKT-32-3 Date (Dw_0:DD MM:YY) (PRN 600D)

MSB	PRN 6013	Day of Week (1 - 7)	8 bits
	PRN 6015	Day of Month (DD) - BCD	8 bits
	PRN 6011	Month (MM) - BCD	8 bits
LSB	PRN 600E	Year (YY) - BCD	8 bits

7.2 Bit Mapped Without Mask (BMP) SLOTs—Bit mapped (BMP) SLOTs are used to encode data that typically contains several binary parameters, such as status bits or flags, grouped into a single byte or several bytes. Bit mapped SLOTs can also be used for discrete output control such as warning lamps where each bit would indicate the state of a particular lamp. The data in these bit mapped SLOTs is not followed by a MASK byte. There can be up to 4 bytes of data without a mask.

7.2.1 BIT MAPPED WITHOUT MASK PARAMETER ASSIGNMENTS

BMP-01-1 MIL Status (PRN 1000)

Length: 1 bit

Item 1: Malfunction Indicator Lamp (MIL)

0	1
Not Commanded On	Commanded On

BMP-08-1 Continuous Evaluation Supported (PRN 1002)

Length: 8 bits

		0	1
Item 1:	Not Used		
Item 2:	Not Used		
Item 3:	Not Used		
Item 4:	Not Used		
Item 5:	Not Used		
Item 6:	Comprehensive Component Monitoring	Not Supported	Supported
Item 7:	Fuel System Monitoring	Not Supported	Supported
Item 8:	Misfire Monitoring	Not Supported	Supported

BMP-08-2 Trip Evaluation Supported (PRN 1002)

Length: 8 bits

		0	1
Item 1:	EGR System	Not Supported	Supported
Item 2:	Oxygen Sensor Heater	Not Supported	Supported
Item 3:	Oxygen Sensor	Not Supported	Supported
Item 4:	A/C System Refrigerant	Not Supported	Supported
Item 5:	Secondary Air System	Not Supported	Supported
Item 6:	Evaporative Purge System	Not Supported	Supported
Item 7:	Heated Catalyst	Not Supported	Supported
Item 8:	Catalyst	NotSupported	Supported

BMP-08-3 Trip Evaluation Complete (PRN 1004)

		0	1
Length:	8 bits		
Item 1:	EGR System	Test Complete	Test Not Complete
Item 2:	Oxygen Sensor Heater	Test Complete	Test Not Complete
Item 3:	Oxygen Sensor	Test Complete	Test Not Complete
Item 4:	A/C System Refrigerant	Test Complete	Test Not Complete
Item 5:	Secondary Air System	Test Complete	Test Not Complete
Item 6:	Evaporative Purge System	Test Complete	Test Not Complete
Item 7:	Heated Catalyst	Test Complete	Test Not Complete
Item 8:	Catalyst	Test Complete	Test Not Complete

BMP-08-4 Fuel System Status (PRN 1008 & 1009)

		0	1
Length:	8 bits		
Item 1:	Reserved		
Item 2:	Reserved		
Item 3:	Reserved		
Item 4:	Closed Loop, Faulty O_2 Sensor	False	True
Item 5:	Open Loop, Detected Fault	False	True
Item 6:	Open Loop, Driving Conditions	False	True
Item 7:	Closed Loop, Using O_2 Sensor	False	True
Item 8:	Open Loop, Not Ready for Closed	False	True

BMP-08-5 Commanded Secondary Air Status (PRN 0012)

		0	1
Length:	8 bits		
Item 1:	Reserved		
Item 2:	Reserved		
Item 3:	Reserved		
Item 4:	Reserved		
Item 5:	Reserved		
Item 6:	Atmosphere/Off	Not Supported	Supported
Item 7:	Downstream - First Catalyst	Not Supported	Supported
Item 8:	Upstream - First Catalyst	Not Supported	Supported

BMP-08-6 O_2 Sensor Location (PRN 0013)

		0	1
Length:	8 bits		
Item 1:	Bank 2 - Sensor 4 (B4 - S2)	Not Present	Present
Item 2:	Bank 2 - Sensor 3 (B4 - S1)	Not Present	Present
Item 3:	Bank 2 - Sensor 2 (B3 - S2)	Not Present	Present
Item 4:	Bank 2 - Sensor 1 (B3 - S1)	Not Present	Present
Item 5:	Bank 1 - Sensor 4 (B2 - S2)	Not Present	Present
Item 6:	Bank 1 - Sensor 3 (B2 - S1)	Not Present	Present
Item 7:	Bank 1 - Sensor 2	Not Present	Present
Item 8:	Bank 1 - Sensor 1	Not Present	Present

BMP-32-1 PIDs Supported 01h - 20h (PRN 0000)

		0	1
Length:	32 bits		
Byte 1:			
Item 1 - 8:	PID 01h - 08h Supported	Not Supported	Supported
Byte 2:			
Item 9 - 16:	PID 09h - 10h Supported	Not Supported	Supported
Byte 3:			
Item 17 - 24:	PID 11h - 18h Supported	Not Supported	Supported
Byte 4:			
Item 25 - 32:	PID 19h - 20h Supported	Not Supported	Supported

BMP-32-2 PIDs Supported 21h - 40h (PRN 0020)

Length:	32 bits	0	1
Byte 1: Item 1 - 8:	Byte 1: PID 21h - 28h Supported	Not Supported	Supported
Byte 2: Item 9 - 16:	Byte 2: PID 29h - 30h Supported	Not Supported	Supported
Byte 3: Item 17 - 24:	Byte 3: PID 31h - 38h Supported	Not Supported	Supported
Byte 4: Item 25 - 32:	Byte 4: PID 39h - 40h Supported	Not Supported	Supported

BMP-32-3 PIDs Supported 41h - 60h (PRN 0040)

Length:	32 bits	0	1
Byte 1: Item 1 - 8:	PID 41h - 48h Supported	Not Supported	Supported
Byte 2: Item 9 - 16:	PID 49h - 50h Supported	Not Supported	Supported
Byte 3: Item 17 - 24:	PID 51h - 58h Supported	Not Supported	Supported
Byte 4: Item 25 - 32:	PID 59h - 60h Supported	Not Supported	Supported

7.3 Bit Mapped With Mask Bytes (BMM) SLOTs---Bit mapped with mask (BMM) SLOTs are used to encode data that typically contains several binary parameters, such as status bits or flags, grouped into a single byte or several bytes. Bit mapped SLOTs can also be used for discrete output control such as warning lamps where each bit would indicate the state of a particular lamp. The data in these bit mapped SLOTs are always followed by a MASK byte which is used to indicate which bits of the data byte are valid. There can be up to 4 bytes of data including the mask bytes. Valid combinations include up to 2 data bytes each with mask.

7.3.1 BIT MAPPED WITH MASK PARAMETER ASSIGNMENTS---None Defined

7.4 Unsigned Numeric (UNM) SLOTs---Unsigned numeric (UNM) SLOTs are used to encode data that is typically associated with information such as temperature, speed, or percent. The SLOT can be 8, 16, 24, ... 56 bits in length (1 to 7 bytes) and may or may not have an offset. Unsigned numeric SLOTs can also be used for sequential data such as month (1 - 12) or day of month (1 - 31). Each SLOT definition contains a field for: resolution per bit; minimum and maximum value; and transfer function. The transfer function defines the relationship between computer units (N) in decimal, and engineering units (E) of the data.

7.4.1 UNSIGNED NUMERIC VARIABLE ASSIGNMENTS---The unsigned numeric variables have been grouped as follows:

- Table 21 - ZEROs SLOT Assignments
- Table 22 - UNM-xx, Short (< 8 Bit) SLOTs
- Table 23 - UNM-08, 8 Bit SLOTs
- Table 24 - UNM-16, 16 Bit SLOTs
- Table 25 - UNM-24, 24 Bit SLOTs
- Table 26 - UNM-32, 32 Bit SLOTs Assignments

TABLE 21---ZEROs SLOT ASSIGNMENTS

Slot #	Description	Length
UNM-01-0	Zero (0)	1 Bit
UNM-02-0	Zero (0)	2 Bits
UNM-03-0	Zero (0)	3 Bits
UNM-04-0	Zero (0)	4 Bits
UNM-05-0	Zero (0)	5 Bits
UNM-06-0	Zero (0)	6 Bits
UNM-07-0	Zero (0)	7 Bits
UNM-08-0	Zero (0)	8 Bits
UNM-16-0	Zero (0)	16 Bits
UNM-24-0	Zero (0)	24 Bits
UNM-32-0	Zero (0)	32 Bits
UNM-40-0	Zero (0)	40 Bits
UNM-48-0	Zero (0)	48 Bits
UNM-56-0	Zero (0)	56 Bits

TABLE 22 - UNM-xx, SHORT (< 8 BIT) SLOTs

Slot #	Scaling (Resolution; 1 Bit =)	Minimum Limit	Maximum Limit	Invalid Range	Transfer Function E =	Transfer Function E =	Comment
01-1	1	0	1	-	N	N	
02-1	1	0	3	-	N	N	
03-1	1	0	7	-	N	N	
04-1	1	0	15	-	N	N	
05-1	1	0	31	-	N	N	
06-1	1	0	63	-	N	N	
07-1	1	0	127	-	N	N	

TABLE 23 - UNM-08, 8 BIT SLOTs

Slot #	Scaling (Resolution; 1 Bit =)	Minimum Limit	Maximum Limit	Invalid Range	Transfer Function N =	Transfer Function E =	Comment
1	1/8000	0	0.031875	-	E * 8000	N / 8000	=0.000125
2	1/4000	0	0.06375	-	E * 4000	N / 4000	=0.00025
3	1/2000	0	0.1275	-	E * 2000	N / 2000	=0.0005
4	1/1000	0	0.255	-	E * 1000	N / 1000	=0.001
5	1/511	0	0.498	-	E * 511	N / 511	=0.001957
6	1/255	0	1	-	E * 255	N / 255	=0.003922
7	1/100	0	+1.27	-	(E+1.28) * 100	(N / 100) -1.28	=0.01 w/ offset
11	1/200	0	1.275	-	E * 200	N / 200	=0.005
15	1/100	0	2.55	-	E * 100	N / 100	=0.01
21	1/64	0	3.98	-	E * 64	N / 64	=0.0156
28	1/32	0	7.969	-	E * 32	N / 32	=0.03125
31	1/25	0	10.2	-	E * 25	N / 25	=0.04
36	1/16	0	15.94	-	E * 16	N / 16	=0.0625
41	1/10	0	25.5	-	E * 10	N / 10	=0.1
51	1/4	0	63.75	-	E * 4	N / 4	=0.25
58	1/3	0	85	-	E * 3	N / 3	=0.333333
61	100/255	0	100	-	E * 2.55	N / 2.55	=0.39215
71	1/2	0	127.5	-	E * 2	N / 2	=0.5
72	1/2	-64	+63.5	-	(E+64) * 2	(N / 2) -64	=0.5 w/ offset
73	1/2	-40	+87.5	-	(E+40) * 2	(N / 2) -40	=0.5 w/ offset
76	2/3	0	170	-	E * 1.5	N / 1.5	=0.666667
77	2/3	0	180	100.3 to 170	E * 1.5	N / 1.5	=0.666667 w/ limits
81	3/4	0	191.25	-	E / 0.75	N * 0.75	=0.75
82	3/4	-90 (00h)	+90 (FDh)	90.75 (F1h - FFh)	(E+90) /0.75	(N*0.75) -90	=0.75 w/ offset
91	100/128	0	199.22	-	E * 1.28	N / 1.28	=0.78125
92	100/128	-100	+99.22	-	(E+100) * 1.28	(N/1.28) -100	=0.78125 w/ Offset
101	1	0	255	-	E	N	=1
102	1	-40	+215	-	E + 40	N - 40	=1 w/ Offset
106	1	-128	+127	-	E + 128	N - 128	=1 w/ Offset
111	3/2	0 (00h)	380 (FDh)	361.5 (F1h - FFh)	E / 1.5	N * 1.5	-
121	2	0	510	-	E / 2	N * 2	-
125	5/2	0	637.5	-	E * 2 / 5	N * 5 / 2	-
131	3	0	765	-	E / 3	N * 3	-
141	4	0	1020	-	E / 4	N * 4	-
151	8	0	2040	-	E / 8	N * 8	-
155	10	0	2550	-	E / 10	N * 10	-
156	14	0	3570	-	E / 14	N * 14	-
161	16	0	4080	-	E / 16	N * 16	-
166	25	0	6375	-	E / 25	N * 25	-
171	32	0	8160	-	E / 32	N * 32	-
181	64	0	16320	-	E / 64	N * 64	-
185	100	0	25500	-	E / 100	N * 100	-
191	128	0	32640	-	E / 128	N * 128	-
201	256	0	65280	-	E / 256	N * 256	-
211	512	0	130560	-	E / 512	N * 512	-
221	1024	0	261120	-	E / 1024	N * 1024	-
231	2048	0	522240	-	E / 2048	N * 2048	-
241	4096	0	1044480	-	E / 4096	N * 4096	-

TABLE 24--UNM-16, 16 BIT SLOTs

Slot #	Scaling (Resolution; 1 Bit =)	Minimum Limit	Maximum Limit	Invalid Range	Transfer Function N =	Transfer Function E =	Comment
2	1/256	0	255.99	-	E * 256	N / 256	=0.003906
3	1/256	-70	185.99	-	(E + 70) * 256	(N / 256) - 70	=0.003906 w/ offset
5	1/128	0	511.99	-	E * 128	N / 128	=0.007813
6	1/64	0	1023.984	-	E * 64	N / 64	=0.015625
11	1/100	0	655.35	-	E * 100	N / 100	=0.01
21	1/10	0	6553.5	-	E * 10	N / 10	=0.1
31	1/4	0	16383.75	-	E * 4	N / 4	=0.25
41	1	0	65535	-	E	N	-

TABLE 26---UNS8-04, 16 BIT SLOTs

Slot #	Scaling (Resolution; 1 Bit =)	Minimum Limit	Maximum Limit	Invalid Range	Transfer Function N =	Transfer Function E =	Comment
11	1/10	0	1677721.5	-	E * 10	N / 10	=0.1
21	128/8000	0	2684338.44	-	(E/128) * 8000	(N * 128) / 8000	=0.016
31	128/4000	0	5368676.88	-	(E/128) * 4000	(N * 128) / 4000	=0.032
41	1/64	0	2682143.06	-	E * 64	N / 64	=0.01563

TABLE 28---UNS8-05, 32 BIT SLOTs

Slot #	Scaling (Resolution; 1 Bit =)	Minimum Limit	Maximum Limit	Invalid Range	Transfer Function N =	Transfer Function E =	Comment
11	1/8000	0	536870.9	-	E * 8000	N / 8000	=0.000125
21	1/4000	0	1073741.8	-	E * 4000	N / 4000	=0.00025
31	1/64	0	67108864	-	E * 64	N / 64	=0.01563

7.5 2's Complement Signed Numeric (SNM) SLOTs---Signed numeric (SNM) SLOTs are represented in 2's complement notation. If the most significant bit of the number is set (one, 1), then the number is negative and the absolute value of the number is found by taking the 2's complement of the number. The 2's complement is found by inverting each bit of the number and then adding a binary one (1) to the result. For example, the number FFh, which has its most significant bit set, corresponds to -1.

7.5.1 2's COMPLEMENT SIGNED NUMERIC VARIABLE ASSIGNMENTS---The 2's complement signed numeric variables are grouped as follows:

- Table 27 - SNM-08, 8 Bit SLOTs

TABLE 27---SNM-08, 8 BIT SLOTs

Slot #	Scaling (Resolution; 1 Bit =)	Minimum Limit	Maximum Limit	Invalid Range	Transfer Function N =	Transfer Function E =	Comment
11	1/2	-64	+63.5	-	E * 2	N / 2	=0.5
21	1	-128	+127	-	E	N	-
41	4	-512	+508	-	E / 4	N * 4	-
51	3/2	-192	+190.5	-	E * 3/2	N * 3/2	-
61	8	-768	+762	-	E / 8	N * 8	-

7.6 State Encoded (SED) SLOTs---State encoded (SED) SLOTs are used for data that can take one of several states such as Day of Week or Wiper Mode. Each SLOT definition contains a field for describing each state within the SLOT. There can be between 1 and 8 bits in any given SLOT with $^n2$ possible states where n is the number of bits in the SLOT.

7.6.1 STATE ENCODED VARIABLE ASSIGNMENTS

SED-02-1 Sub-System Category Reference Letter (PRN 1005)

Length:	2 bits (0 - 3)
0	"P" = Powertrain
1	"C" = Chassis
2	"B" = Body
3	"U" = Undefined

SED-02-2 Most Significant Digit of Trouble Code (PRN 1006)

Length:	2 bits (0 - 3)
0	"0"
1	"1"
2	"2"
3	"3"

SED-02-3 Transmission Lock-up Status (PRN 1807)

Length:	2 bits (0 - 3)
0	Unlock
1	Partial Lock
2	Full Lock
3	Invalid

SED-04-1 Day of the Week (PRN 6012)

Length:	4 bits (0 - F)
0	Unknown
1	Sunday
2	Monday
3	Tuesday
4	Wednesday
5	Thursday
6	Friday
7	Saturday
8 - F	Invalid

SED-04-2 Month (PRN 6010)

Length:	4 bits (0 - F)
0	Unknown
1	January
2	February
3	March
4	April
5	May
6	June
7	July
8	August
9	September
A	October
B	November
C	December

D - F	Invalid

SED-06-1 Transmission Gear Engaged (PRN 1808)

Length:	6 bits (00 - 3F)
00	Neutral
01	Reverse
02	Forward 1
04	Forward 2
08	Forward 3
10	Forward 4
20	Forward 5
Others	Invalid

SED-08-1 Wiper Mode (PRN A003)

Length:	8 bits (00 - FF)
00	Invalid
01	Off
02	Intermittent
03	Low Speed
04	Medium Speed
05	High Speed
06	Pulse
07 - FF	Invalid

SED-08-2 Day of the Week (PRN 6013)

Length:	8 bits (00 - FF)
00	Unknown
01	Sunday
02	Monday
03	Tuesday
04	Wednesday
05	Thursday
06	Friday
07	Saturday
08 - FF	Invalid

SED-08-3 Day of Month (PRN 6014)

Length:	8 bits (00 - FF)
00	Invalid
01	1st
02	2nd
03	3rd
04	4th
05	5th
06	6th
07	7th
08	8th
09	9th
0A	10th
0B	11th
0C	12th
0D	13th
0E	14th
0F	15th
10	16th
11	17th
12	18th
13	19th
14	20th
15	21st
16	22nd
17	23rd
18	24th
19	25th
1A	26th
1B	27th
1C	28th
1D	29th
1E	30th
1F	31st
20 - FF	Invalid

SED-08-4 Transmission Range (PRN 1806, 1809, 180D, & 180E)

Length:	8 bits (00 - FF)
00	Invalid
01	Reverse
02	Forward 1
04	Forward 2
08	Forward 3
10	Forward 4
20	Forward 5
40	Forward 6/Park
80	Neutral
Others	Invalid

SED-08-5 Ignition Switch Position (PRN 1047)

Length:	8 bits (00 - FF)
00	Invalid
01	ACC
02	OFF/LOCK
04	OFF/UNLOCK
08	RUN
10	START
Others	Invalid

SED-08-6 Transmission Transfer Case (4WD) (PRN 180A)

Length:	8 bits (00 - FF)
00	Invalid
01	Neutral
02	Two Wheel Drive
03	Four Wheel Drive - Low
04	Four Wheel Drive - High
05 - FF	Invalid

SED-08-07 Door Lock Cylinder State (PRN C002)

Length:	8 bits (00 - FF)
00	Key Out
01	Key In Lock Position
02	Key In Unlock Position
03 - FF	Invalid

7.7 ASCII Encoded (ASC) SLOTs—ASCII (ASC) SLOTs are used to encode ASCII data. The least significant 7 bits represent the standard ASCII codes from 0 to 127. The most significant bit is reserved at this time but may be assigned a special function in the future. Several ASCII characters can be included in a single message by placing up to 7 ASCII characters sequentially in the data field. This allows a character string of up to 7 characters to be sent in a single message.

The ASCII character set is included in Table 27.

7.7.1 ASCII ENCODED VARIABLE ASSIGNMENTS

ASC-08-1 One ASCII Character

Length:	8 bits
Byte 1:	One ASCII Character

ASC-16-1 Two ASCII Characters

Length:	16 bits
Byte 1:	Left Most Character
Byte 2:	Right Most Character

ASC-24-1 Three ASCII Characters

Length:	24 bits
Byte 1:	Left Most Character
Byte 2:	Middle Character
Byte 3:	Right Most Character

ASC-32-1 Four ASCII Characters

Length:	32 bits
Byte 1:	Left Most Character
Byte 2:	Middle Left Character
Byte 3:	Middle Right Character
Byte 4:	Right Most Character

Five ASCII Characters
ASC-40-1
Length: 40 bits
Byte 1: Left Most Character
Byte 2: Middle Left Character
Byte 3: Middle Character
Byte 4: Middle Right Character
Byte 5: Right Most Character

Six ASCII Characters
ASC-48-1
Length: 48 bits
Byte 1: Left Most Character
Byte 2: Middle Left Character
Byte 3: Middle Middle Left Character
Byte 4: Middle Middle Right Character
Byte 5: Middle Right Character
Byte 6: Right Most Character

Seven ASCII Characters
ASC-56-1
Length: 56 bits
Byte 1: Left Most Character
Byte 2: Middle Left Character
Byte 3: Middle Middle Left Character
Byte 4: Middle Character
Byte 5: Middle Middle Right Character
Byte 6: Middle Right Character
Byte 7: Right Most Character

7.13 ASCII Character Set---The conversion chart, Table 28, can be used to convert from a two-digit (one byte) hexadecimal number to an ASCII character or from an ASCII character to a two-digit hexadecimal number.

TABLE 28-- ASCII CONVERSION CHART

Bits 4 to 6 / First Hex Digit (MSB) → / Bits 0 to 3 (LSB) ↓	0	1	2	3	4	5	6	7
0	NUL	DLE	SP	0	@	P	`	p
1	SOH	DC1	!	1	A	Q	a	q
2	STX	DC2	"	2	B	R	b	r
3	ETX	DC3	#	3	C	S	c	s
4	EOT	DC4	$	4	D	T	d	t
5	ENQ	NAK	%	5	E	U	e	u
6	ACK	SYN	&	6	F	V	f	v
7	BEL	ETB	'	7	G	W	g	w
8	BS	CAN	(	8	H	X	h	x
9	HT	EM	)	9	I	Y	i	y
A	LF	SUB	*	:	J	Z	j	z
B	VT	ESC	+	;	K	[	k	{
C	FF	FS	,	<	L	\	l	|
D	CR	GS	-	=	M	]	m	}
E	SO	RS	.	>	N	^	n	~
F	SI	US	/	?	O	_	o	DEL

7.8 Binary Coded Decimal (BCD) SLOTs---BCD SLOTs are similar to ASCII SLOTs and are used to encode BCD data. The upper nibble is used to represent the most significant digit in a two-digit number and the lower nibble the least significant digit. For example, the data value 38h would represent 38 decimal. Invalid data ranges include any value that has either nibble greater than 9 (i.e., A, B, ..., F in either nibble). Therefore, a valid value can represent a number from 0 to 9. Several BCD numbers can be included in a single message by packing up to 14 BCD digits sequentially in the data field. This allows any number from 0 to 99,999,999,999,999 to be sent in a single message.

7.8.1 Binary Coded Decimal (BCD) Variable Assignments

BCD-4x-1
1 digit
Length: 4 bits
Scaling (Resolution): 1 bit = 1 (BCD)
Limit:
Minimum: 0
Maximum: 9

BCD-8-1
2 digits
Length: 8 bits
Scaling (Resolution): 1 bit = 1 (BCD)
Limit:
Minimum: 00
Maximum: 99

BCD-12-1
3 digits
Length: 12 bits
Scaling (Resolution): 1 bit = 1 (BCD)
Limit:
Minimum: 000
Maximum: 999

BCD-16-1
4 digits
Length: 16 bits
Scaling (Resolution): 1 bit = 1 (BCD)
Limit:
Minimum: 0000
Maximum: 9999

BCD-20-1
5 digits
Length: 20 bits
Scaling (Resolution): 1 bit = 1 (BCD)
Limit:
Minimum: 00000
Maximum: 99999

BCD-24-1
6 digits
Length: 24 bits
Scaling (Resolution): 1 bit = 1 (BCD)
Limit:
Minimum: 000000
Maximum: 999999

BCD-28-1
7 digits
Length: 28 bits
Scaling (Resolution): 1 bit = 1 (BCD)
Limit:
Minimum: 0000000
Maximum: 9999999

BCD-32-1
8 digits
Length: 32 bits
Scaling (Resolution): 1 bit = 1 (BCD)
Limit:
Minimum: 00000000
Maximum: 99999999

BCD-36-1
9 digits
Length: 36 bits
Scaling (Resolution): 1 bit = 1 (BCD)
Limit:
Minimum: 000000000
Maximum: 999999999

BCD-40-1
10 digits
Length: 40 bits
Scaling (Resolution): 1 bit = 1 (BCD)
Limit:
Minimum: 0000000000
Maximum: 9999999999

BCD-44-1
11 digits
Length: 44 bits
Scaling (Resolution): 1 bit = 1 (BCD)
Limit:
Minimum: 00000000000
Maximum: 99999999999

BCD-48-1
12 digits
Length: 48 bits
Scaling (Resolution): 1 bit = 1 (BCD)
Limit:
Minimum: 000000000000
Maximum: 999999999999

BCD-52-1 13 digits
Length: 52 bits
Scaling (Resolution): 1 bit = 1 (BCD)
Limit:
Minimum: 0000000000000
Maximum: 9999999999999

BCD-56-1 14 digits
Length: 56 bits
Scaling (Resolution): 1 bit = 1 (BCD)
Limit:
Minimum: 00000000000000
Maximum: 99999999999999

7.9 **Signed Floating Point [Scientific Notation] (SFP) SLOT**—The Signed Floating Point (SFP) SLOT is used to encode data that needs to be represented in floating point arithmetic, and always includes a leading sign character. The format exactly follows the ANSI/IEEE Standard (Std 754-1985) Single format. Please note that the data byte boundaries of the transmitted frame do not align with the boundaries of this format. The floating point parameter is sent as a 32 bit (4 byte) variable. The bit order is shown in Figure 14.

7.9.1 SIGNED FLOATING POINT VARIABLE ASSIGNMENT

SFP-32-1 Floating Point

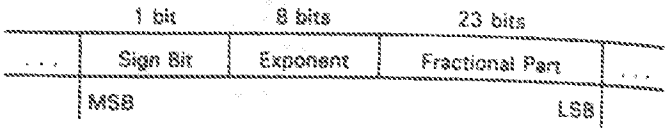


FIGURE 14—SIGNED FLOATING POINT (SCIENTIFIC NOTATION) (SFP) SLOT

8. Multiple Frame, Single Parameter Format—This section defines the method of encoding long parameters that require more than one frame to complete. The first data byte for this format is a sequence number as shown in Figure 15. The sequence byte consists of an upper nibble that identifies this frame by number in the sequence. The lower nibble is the total number of frames that make up this grouping. The sequence byte is followed by up to the maximum number of data bytes allowed by SAE J1850, for each frame. The entire parameter is thus built up from the total number of frames shown in the sequence tracking byte, in the order carried in that byte. The data field format will thus have an order indicated by Figure 16.

A simple example of this format is shown in Figures 17, 18, and 19, sending an ASCII string of characters.

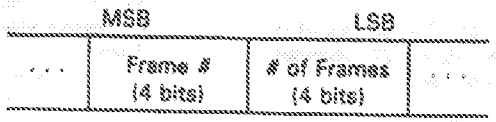


FIGURE 15—SEQUENCE TRACKING BYTE

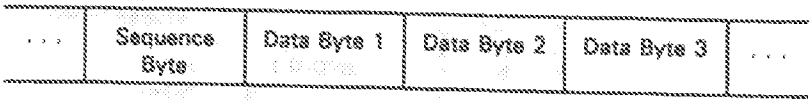


FIGURE 16—MULTIPLE FRAME, SINGLE PARAMETER FIELD

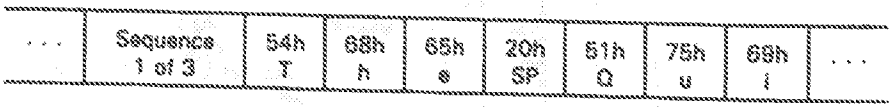


FIGURE 17—FIRST SEQUENCE FRAME

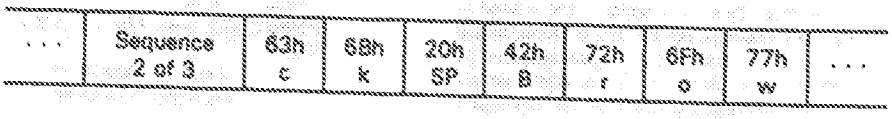


FIGURE 18—SECOND SEQUENCE FRAME

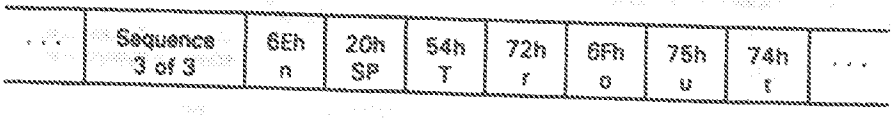


FIGURE 19—LAST SEQUENCE FRAME

Page 731 of 1656 OMEGA EXHIBIT 2037

CLASS B DATA COMMUNICATION NETWORK MESSAGES—PART 3: FRAME IDs FOR SINGLE BYTE FORMS OF HEADERS—SAE J2178/3 SEP93

SAE Recommended Practice

Issued by the SAE Vehicle Network for Multiplexing and Data Communications Standards Committee approved September 1993.

TABLE OF CONTENTS

1 Scope
1.1 Standardized Parameter Definitions
2 References
2.1 Applicable Documents
2.2 Related Publications
2.3 Terms and Definitions
3.1 Data [Data Field]
3.1.2 Frame
3.1.3 Header [Header Field]
3.1.4 In-Frame Response (IFR) Type
3.1.5 Message
3.1.6 Parameter
3.1.7 Priority
3.1.8 Response Data
3.4 Abbreviations and Acronyms
3.5 General Information
3.5.1 Document Overview
3.5.2 Parameter Reference Number (PRN)
3.5.3 Message Identification (FRAME ID)
3.5.3.1 PRN Assignments
3.5.3.2 In-Frame Response (IFR) Type
3.5.3.3 Repetition Rate
3.5.3.4 CRC Byte Requirements
4 Frame IDs for Single Byte Forms of Headers

1. *Scope*—This SAE Recommended Practice defines the information carried in the header and data fields of nondiagnostic messages for inter-vehicle serial communications based on SAE J1850 Class B networks. This document describes and specifies the header fields, data fields, field sizes, coding representations, and data positions used within messages.

The general structure of a SAE J1850 message frame without in-frame response is shown in Figure 1. The structure of a SAE J1850 message with in-frame response is shown in Figure 2. Figures 1 and 2 also show the scope of those fields defined by this document for nondiagnostic messages. Refer to SAE J1979 for specifications of emissions-related diagnostic message header and data fields. Refer to SAE J2190 for the definition of other diagnostic message header and data fields. The description of the network interface hardware, basic protocol definition, the electrical specifications, and the CRC algorithm is given in SAE J1850.

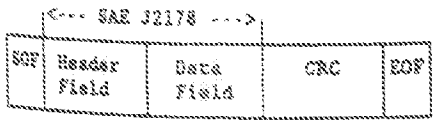


FIGURE 1—SCOPE OF SAE J2178 FOR A SAE J1850 FRAME WITHOUT IN-FRAME RESPONSE

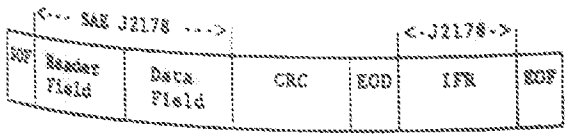


FIGURE 2—SCOPE OF SAE J2178 FOR A SAE J1850 FRAME WITH IN-FRAME RESPONSE (IFR)

SAE J1850 defines two and only two formats of message headers. They are the Single Byte header format and the Consolidated header format. The Consolidated header format has two forms: a single byte form and a three byte form. This document covers all of these formats and forms to identify the contents of messages which could be sent on a SAE J1850 network.

This document consists of four parts, each published separately.

Part 1 of SAE J2178 (Titled: Detailed Header Formats and Physical Address Assignments) describes the two allowed forms of message header formats: single byte and consolidated. It also contains the physical node address range assignments for the typical subsystems of an automobile.

Part 2 of SAE J2178 (Titled: Data Parameter Definitions) defines the standard parametric data which may be exchanged on SAE J1850 (Class B) networks. The parameter scaling, ranges, and transfer functions are specified. Messages which refer to these parametric definitions shall always adhere to these parametric definitions. It is intended that at least one of the definitions for each parameter in this part match the SAE J1979 definition. The details of this part are fully described in 3.1.

Part 3 of SAE J2178 (this part, Titled: Frame IDs for Single Byte Forms of Headers) defines the message assignments for the single byte header format and the one byte form of the consolidated header format.

Part 4 of SAE J2178 (Titled: Target Address (Second Byte) for Three Byte Headers) defines the message assignments for the second byte in the three byte form of the consolidated header format.

1.1 Standardized Parameter Definitions—The parameters used to describe data variables are one of the most important functions of this document. To achieve commonality of messages in Class B networks, the data parameters must become standardized. This applies to data parameter definitions for use during normal vehicle operations as well as during diagnostic operations. By using common parameter definitions for nondiagnostic and diagnostic functions on the network, the modules which form the network can maintain one image or description of a data parameter.

Where parameters have been defined in the Diagnostic Test Modes documents (SAE J1979 and J2190), such as Parameter Identifiers for diagnostic purposes, the definitions in Part 2 of this document match the diagnostic definition.

SAE J2178, Part 2 defines the parameters to be used for nondiagnostic and diagnostic data format definitions. For new parameter definitions which are needed in the future, the new definitions, if they are expected to become widely used, must be integrated into this document for commonality across these types of applications. Of course, manufacturers are free to assign their own definitions to data parameters which are unique or proprietary to their products. They are, however, restricted to using the "Manufacturer Reserved" message header assignments in Parts 3 and 4 of this document when using these unique or proprietary data parameter definitions.

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.

SAE J1850—Class B Data Communication Network Interface

SAE J1979—E/E Diagnostic Test Modes

SAE J2178/1—Detailed Header Formats and Physical Address Assignments

SAE J2178/2—Data Parameter Definitions

SAE J2178/4—Target Address (Second Byte) for Three Byte Headers (Draft)

SAE J2190—Enhanced E/E Diagnostic Test Modes

2.2 Related Publications—The following publications are provided for information purposes only and are not a required part of this document.

SAE J1213/1—Glossary of Vehicle Networks for Multiplex and Data Communications

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

2.3 Terms and Definitions

2.3.1 DATA (DATA FIELD)—Data and data field are used interchangeably in this document and they both refer to a field within a frame that may include bytes with parameters pertaining to the message and/or secondary ID and/or extended addresses and/or test modes which further defines a particular message content being exchanged over the network.

OMEGA EXHIBIT 2037

2.3.2 FRAME—A frame is one complete transmission of information which may or may not include an In-Frame Response. The frame is enclosed by the start of frame and end of frame symbols. For Class B networks, each frame contains one and only one message (see "message" 2.3.5).

2.3.3 HEADER [HEADER FIELD]—The header (or header field, used interchangeably) is a one or three byte field within a frame which contains information about the message priority, message source and target addressing, message type, and in-frame response type.

2.3.4 IN-FRAME RESPONSE (IFR) TYPE—The IFR type identifies the form of the in-frame response which is expected within that message.

2.3.5 MESSAGE—A message consists of all of the bytes of a frame excluding the delimiter symbols (SOF, EOD, EOF, NB).

2.3.6 PARAMETER—A parameter is the variable quantity included in some messages. The parameter value, scaling, offset, units, transfer function, etc., are unique to each particular message. (The assigned parameters are contained herein.)

2.3.7 PRIORITY—The priority describes the rank order and precedence of a message. Based upon the SAE J1850, Class B arbitration process, the message with the highest priority will win arbitration.

2.3.8 RESPONSE DATA—The response data is the information from a node on the network in response to a request from another node on the network. This may be an in-frame response or a report type of message.

2.4 Abbreviations and Acronyms

CRC - Cyclic Redundancy Check
EOD - End of Data
EOF - End of Frame
ID - Identifier
IFR - In-Frame Response
LSB - Least Significant Bit / Byte
MSB - Most Significant Bit / Byte
NB - Normalization Bit
PKT - Multiple Parameter Packet SLOT
PRN - Parameter Reference Number
SLOT - Scaling, Limit, Offset, and Transfer Function
SOF - Start of Frame

3. General Information

3.1 Document Overview—The messages defined by this document are specified for networks using one byte headers or the single byte form of the consolidated header as specified in SAE J1850. This document focuses on the Frame ID which is the first byte of the message. The first byte of the one byte header is defined in Section 4 under Frame ID as an 8 Bit hexadecimal number and the first byte of the single byte form of the consolidated header is defined under 7 Bit as a hexadecimal number. Bit four (H bit) of the 7 Bit header is always a logic "1" (see Section 5 of SAE J2178 Part 1). The information in the header field implicitly defines the target, source, priority and message type information, while the data field contains additional addressing and parametric information (see Section 4 of SAE J2178 Part 1). The header defines the Message Identifier or Frame ID and becomes the name that is broadcast normally periodically to all the nodes on the network.

This document describes the overall structure of messages and is expected to have wide application. Designers are required to use the defined messages on SAE J1850 networks in the exact way that they are defined here. There are a large number of message codes which are reserved for each manufacturer to define. If the user cannot find a needed message, he or she is expected to define a manufacturer-specific message in these reserved codes. Therefore, messages on different manufacturer's products using these "Manufacturer Reserved" codes will only have meaning for that manufacturer or specific vehicle. These will most likely be different between manufacturers. The codes that are defined here, however, shall always carry the same meaning from one manufacturer to another and from one model and year to the next.

3.2 Parameter Reference Number (PRN)—With the Single Byte form of header, the Frame ID corresponds with a particular Parameter Reference Number (PRN) or a grouping of PRNs (see Section 6 of SAE J2178 Part 2). The PRN is an arbitrarily assigned number and defines the following:

a. Length of data in number of bits
b. Units
c. Scaling, Limit, Offset, and Transfer Function, i.e., SLOT (see Section 7 of SAE J2178 Part 2)
d. Type or category of data

SAE J2178 Part 2, Section 7 defines the following data Types:

(1) BMP Bit Mapped
(2) UNM Unsigned Numeric
(3) SNM 2's Complement Signed Numeric
(4) SED State Encoded
(5) ASC ASCII Encoded
(6) BCD Binary Coded Decimal
(7) SFP Signed Floating Point (Scientific Notation)

3.3 Message Identification (FRAME ID)—The FRAME ID of the single byte header implicitly and uniquely defines the following characteristics of the message:

a. The message priority
b. The data content of the message specified by a PRN or packet of PRNs
c. The length of message
d. Source of the message
e. Type of the message
f. The event or repetition rate for transmission
g. CRC byte requirements

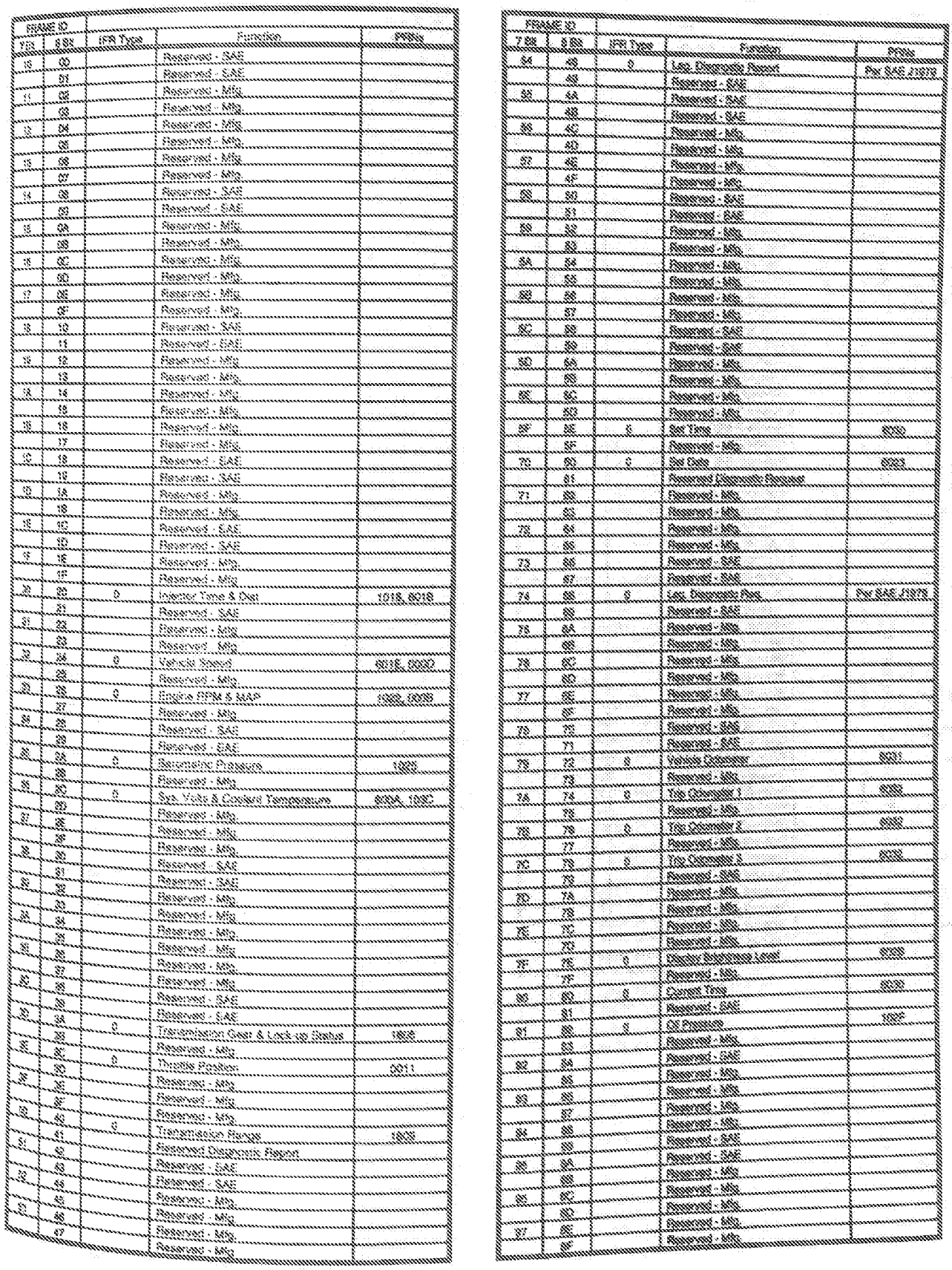
3.3.1 PRN ASSIGNMENTS—A FRAME ID shall have one or more PRNs assigned to it. Some PRNs may be composed of a packet (PKT) of PRNs (see paragraph 7.1 of SAE J2178 Part 2). The bytes of the data field shall be composed of the parameter given in the "PRNs" column of the figure defined in Section 4. When more than one PRN is shown, the data field shall contain the PRNs in the order given left to right.

3.3.2 IN-FRAME RESPONSE (IFR) TYPE—The IFR Type shall be given under "IFR Type" column of the figure defined in Section 4. The different IFR Types are defined in Section 3 of J2178 Part 1.

3.3.3 REPETITION RATE—The vehicle manufacturer shall choose which message frames are event driven or defined by a repetition rate. Refer to SAE J2178 Part 1 Appendix A for further information on event- or time-based message frames.

3.3.4 CRC BYTE REQUIREMENTS—The CRC byte requirements shall be defined by the manufacturer as specified by SAE J1850.

4. Frame IDs for Single Byte Forms of Headers—Figure 3 defines the Frame ID for one byte headers and the first byte of the single byte form of the consolidated header.



FRAME ID				
7 Bit	8 Bit	IFR Type	Function	PIDs
16	20		Reserved - SAE	
	21		Reserved - SAE	
17	22		Reserved - Mfg.	
	23		Reserved - Mfg.	
18	24		Reserved - Mfg.	
	25		Reserved - Mfg.	
19	26		Reserved - Mfg.	
	27		Reserved - Mfg.	
1A	28		Reserved - SAE	
	29		Reserved - SAE	
1B	2A		Reserved - Mfg.	
	2B		Reserved - Mfg.	
1C	2C		Reserved - Mfg.	
	2D		Reserved - Mfg.	
1D	2E		Reserved - Mfg.	
	2F		Reserved - Mfg.	
1E	30		Reserved - SAE	
	31		Reserved - SAE	
1F	32		Reserved - Mfg.	
	33		Reserved - Mfg.	
20	34		Reserved - Mfg.	
	35		Reserved - Mfg.	
21	36		Reserved - Mfg.	
	37		Reserved - Mfg.	
22	38		Reserved - SAE	
	39		Reserved - SAE	
23	3A		Reserved - Mfg.	
	3B		Reserved - Mfg.	
24	3C		Reserved - SAE	
	3D		Reserved - SAE	
25	3E		Reserved - Mfg.	
	3F		Reserved - Mfg.	
26	40	0	Intertor Time & Dist	101B, 801B
	41		Reserved - SAE	
27	42		Reserved - Mfg.	
	43		Reserved - Mfg.	
28	44	0	Vehicle Speed	801E, 802D
	45		Reserved - Mfg.	
29	46	0	Engine RPM & MAP	100D, 0B0B
	47		Reserved - Mfg.	
2A	48		Reserved - SAE	
	49		Reserved - SAE	
2B	4A	0	Barometric Pressure	133E
	4B		Reserved - Mfg.	
2C	4C	0	Sys. Volts & Coolant Temperature	805A, 105C
	4D		Reserved - Mfg.	
2D	4E		Reserved - Mfg.	
	4F		Reserved - Mfg.	
2E	50		Reserved - SAE	
	51		Reserved - SAE	
2F	52		Reserved - Mfg.	
	53		Reserved - Mfg.	
30	54		Reserved - Mfg.	
	55		Reserved - Mfg.	
31	56		Reserved - SAE	
	57		Reserved - SAE	
32	58	0	Transmission Gear & Lock up Status	1B0B
	59		Reserved - Mfg.	
33	5A	0	Throttle Position	9011
	5B		Reserved - Mfg.	
34	5C		Reserved - Mfg.	
	5D		Reserved - Mfg.	
35	5E	0	Transmission Range	1B0B
	5F		Reserved Diagnostic Report	
36	60		Reserved - SAE	
	61		Reserved - SAE	
37	62		Reserved - Mfg.	
	63		Reserved - Mfg.	
38	64		Reserved - Mfg.	
	65		Reserved - Mfg.	

FRAME ID				
7 Bit	8 Bit	IFR Type	Function	PIDs
64	66	0	Last Diagnostic Report	Per SAE J1979
	67		Reserved - SAE	
65	68		Reserved - SAE	
	69		Reserved - SAE	
66	6A		Reserved - Mfg.	
	6B		Reserved - Mfg.	
67	6C		Reserved - Mfg.	
	6D		Reserved - Mfg.	
68	6E		Reserved - Mfg.	
	6F		Reserved - Mfg.	
69	70		Reserved - SAE	
	71		Reserved - SAE	
6A	72		Reserved - Mfg.	
	73		Reserved - Mfg.	
6B	74		Reserved - Mfg.	
	75		Reserved - Mfg.	
6C	76		Reserved - SAE	
	77		Reserved - SAE	
6D	78		Reserved - Mfg.	
	79		Reserved - Mfg.	
6E	7A		Reserved - Mfg.	
	7B		Reserved - Mfg.	
6F	7C	0	Set Time	801D
	7D		Reserved - Mfg.	
70	7E	0	Set Date	8023
	7F		Reserved Diagnostic Request	
71	80		Reserved - Mfg.	
	81		Reserved - Mfg.	
72	82		Reserved - Mfg.	
	83		Reserved - Mfg.	
73	84		Reserved - SAE	
	85		Reserved - SAE	
74	86	0	Last Diagnostic Fail	Per SAE J1979
	87		Reserved - SAE	
75	88		Reserved - Mfg.	
	89		Reserved - Mfg.	
76	8A		Reserved - Mfg.	
	8B		Reserved - Mfg.	
77	8C		Reserved - Mfg.	
	8D		Reserved - Mfg.	
78	8E		Reserved - SAE	
	8F		Reserved - SAE	
79	90		Reserved - Mfg.	
	91		Reserved - Mfg.	
7A	92	0	Trip Odometer 1	802C
	93		Reserved - Mfg.	
7B	94	0	Trip Odometer 2	802C
	95		Reserved - Mfg.	
7C	96	0	Trip Odometer 3	802C
	97		Reserved - SAE	
7D	98		Reserved - Mfg.	
	99		Reserved - Mfg.	
7E	9A		Reserved - Mfg.	
	9B		Reserved - Mfg.	
7F	9C	0	Engine Benchmark Level	800B
	9D		Reserved - Mfg.	
80	9E	0	Current Time	8030
	9F		Reserved - SAE	
81	A0	0	Oil Pressure	1002
	A1		Reserved - Mfg.	
82	A2		Reserved - SAE	
	A3		Reserved - Mfg.	
83	A4		Reserved - Mfg.	
	A5		Reserved - Mfg.	
84	A6		Reserved - Mfg.	
	A7		Reserved - Mfg.	
85	A8		Reserved - SAE	
	A9		Reserved - SAE	
86	AA		Reserved - Mfg.	
	AB		Reserved - Mfg.	
87	AC		Reserved - Mfg.	
	AD		Reserved - Mfg.	
	AE		Reserved - Mfg.	

FIGURE 3—FRAME IDs FOR SINGLE BYTE FORMS OF HEADERS

Page 734 of 1656 OMEGA EXHIBIT 2037

FRAME ID				
7 Bit	8 Bit	IFR Type	Function	PIDs
89	09	0	Fuel Economy, Present	8901, 8902
	0A		Reserved - Mfg.	
8B	0B	0	Current Data	8B03
	0C		Reserved - Mfg.	
8D	0D	0	Ign. Off Time	8D0C
	0E		Reserved - Mfg.	
8F	0F		Reserved - SAE	
	10		Reserved - SAE	
91	11		Reserved - SAE	
	12		Reserved - Mfg.	
93	13		Reserved - Mfg.	
	14	0	Accum. Ign. On Time	9305
95	15		Reserved - Mfg.	
	16		Reserved - SAE	
97	17		Reserved - Mfg.	
	18	0	Fuel Consumed	9708
99	19		Reserved - Mfg.	
	1A	0	Distance to Empty	9A27
9B	1B		Reserved - SAE	
	1C	0	Fuel Economy, Average	9C28, 9C29
9D	1D		Reserved - Mfg.	
	1E	0	Fuel Tank Level	9E06
9F	1F		Reserved - Mfg.	
	20		Reserved - Mfg.	
A1	21		Reserved - Mfg.	
	22		Reserved - SAE	
A3	23		Reserved - SAE	
	24		Reserved - Mfg.	
A5	25		Reserved - Mfg.	
	26		Reserved - Mfg.	
A7	27		Reserved - Mfg.	
	28		Reserved - Mfg.	
A9	29		Reserved - Mfg.	
	2A		Reserved - Mfg.	
AB	2B		Reserved - Mfg.	
	2C		Reserved - Mfg.	
AD	2D		Reserved - Mfg.	
	2E		Reserved - SAE	
AF	2F		Reserved - SAE	
	30		Reserved - Mfg.	
B1	31		Reserved - Mfg.	
	32		Reserved - Mfg.	
B3	33		Reserved - Mfg.	
	34		Reserved - Mfg.	
B5	35		Reserved - Mfg.	
	36		Reserved - Mfg.	
B7	37		Reserved - Mfg.	
	38		Reserved - Mfg.	
B9	39		Reserved - Mfg.	
	3A		Reserved - Mfg.	
BB	3B		Reserved - Mfg.	
	3C		Reserved - Mfg.	
BD	3D		Reserved - Mfg.	
	3E		Reserved - Mfg.	
BF	3F		Reserved - Mfg.	
	40		Reserved - Mfg.	
C1	41		Reserved - SAE	
	42		Reserved - SAE	
C3	43		Reserved - Mfg.	
	44		Reserved - Mfg.	
C5	45		Reserved - Mfg.	
	46		Reserved - Mfg.	
C7	47		Reserved - Mfg.	

FRAME ID				
7 Bit	8 Bit	IFR Type	Function	PIDs
C9	48		Reserved - Mfg.	
	49		Reserved - SAE	
CB	4A		Reserved - SAE	
	4B		Reserved - Mfg.	
CD	4C	0	Outside Temperature	8D01
	4D		Reserved - Mfg.	
CF	4E		Reserved - Mfg.	
	4F		Reserved - Mfg.	
D1	50		Reserved - Mfg.	
	51		Reserved - Mfg.	
D3	52		Reserved - Mfg.	
	53		Reserved - Mfg.	
D5	54		Reserved - Mfg.	
	55		Reserved - Mfg.	
D7	56		Reserved - Mfg.	
	57		Reserved - Mfg.	
D9	58		Reserved - SAE	
	59		Reserved - SAE	
DB	5A		Reserved - Mfg.	
	5B		Reserved - Mfg.	
DD	5C		Reserved - Mfg.	
	5D		Reserved - Mfg.	
DF	5E		Reserved - Mfg.	
	5F		Reserved - Mfg.	
E1	60		Reserved - Mfg.	
	61		Reserved - SAE	
E3	62		Reserved - Mfg.	
	63		Reserved - Mfg.	
E5	64		Reserved - Mfg.	
	65		Reserved - Mfg.	
E7	66		Reserved - Mfg.	
	67		Reserved - Mfg.	
E9	68		Reserved - Mfg.	
	69		Reserved - SAE	
EB	6A		Reserved - SAE	
	6B		Reserved - Mfg.	
ED	6C		Reserved - Mfg.	
	6D		Reserved - Mfg.	
EF	6E		Reserved - Mfg.	
	6F		Reserved - Mfg.	
F1	70		Reserved - Mfg.	
	71		Reserved - Mfg.	
F3	72		Reserved - Mfg.	
	73		Reserved - Mfg.	
F5	74		Reserved - Mfg.	
	75		Reserved - Mfg.	
F7	76		Reserved - Mfg.	
	77		Reserved - Mfg.	
F9	78		Reserved - SAE	
	79		Reserved - SAE	
FB	7A		Reserved - Mfg.	
	7B		Reserved - Mfg.	
FD	7C		Reserved - Mfg.	
	7D		Reserved - Mfg.	
FF	7E		Reserved - Mfg.	
	7F		Reserved - Mfg.	

FIGURE 3---FRAME IDs FOR SINGLE BYTE FORMS OF HEADERS (CONTINUED)

CLASS B DATA COMMUNICATION NETWORK MESSAGES—MESSAGE DEFINITIONS FOR THREE BYTE HEADERS—SAE J2178/4 FEB95

SAE Recommended Practice

Report of the SAE Vehicle Network for Multiplex and Data Communications Standards Committee approved February 1995.

TABLE OF CONTENTS

1. Scope
2. References
2.1 Related Publications
2.1.1 SAE Publications
2.1.2 ANSI Publication
2.2 Abbreviations and Acronyms
3. Terms and Definitions
4. General Information
5. Functional Target Address Assignments (Primary ID)
6. Function Read Target Address Assignments
7. Message Assignments
7.1 Engine Torque
7.2 Engine Air Intake
7.3 Throttle
7.4 Air Conditioning Clutch
7.5 Engine RPM
7.6 Wheels
7.7 Vehicle Speed
7.8 Traction Control
7.9 Brakes
7.10 Steering / Steering Wheel
7.11 Transmission / Transaxle / PRNDL
7.12 Engine Sensors - Other
7.13 Engine Coolant
7.14 Engine Oil
7.15 Engine Systems - Other
7.16 Suspension
7.17 Vehicle Speed Control
7.18 Charging System
7.19 Electrical Energy Management
7.20 Odometer
7.21 Fuel System
7.22 Ignition Switch / Starter
7.23 Tell Tales
7.24 Climate Control (HVAC)
7.25 Window Wiper / Washer
7.26 Mirrors
7.27 Door Locks
7.28 Personal Access
7.29 Seat Motion / Control
7.30 Windows
7.31 Steering Column
7.32 Seat Switches
7.33 Restraints
7.34 Exterior Lamps Outage
7.35 Exterior Lamps
7.36 Interior Lamps Outage
7.37 Interior Lamps
7.38 Time
7.39 Defrost
7.40 Displays
7.41 Exterior Environment
7.42 Interior Environment
7.43 Time / Date
7.44 Vehicle Identification
7.45 Network Control
8. Extended Address Assignments
8.1 Brakes, Tires, and Wheels
8.2 HVAC Zones
8.3 Window Wiper / Washer, Defrost, and Photocell
8.4 Mirrors
8.5 Doors and Door Locks
8.6 Seats and Restraints
8.7 Windows
8.8 External Lamps
8.9 Internal Lamps

1. *Scope*—This SAE Recommended Practice defines the information contained in the header and data fields of non-diagnostic messages for automotive serial communications based on SAE J1850 Class B networks. This document describes and specifies the header fields, data fields, field sizes, scaling, representations, and data positions used within messages.

The general structure of a SAE J1850 message frame without in-frame response is shown in Figure 1. The structure of a SAE J1850 message with in-frame response is shown in Figure 2. Figures 1 and 2 also show the scope of frame fields defined by this document for non-diagnostic messages. Refer to SAE J1979 for specifications of emissions related diagnostic message header and data fields. Refer to SAE J2190 for the definition of other diagnostic data fields. The description of the network interface hardware, basic protocol definition, the electrical specifications, and the CRC byte are given in SAE J1850.

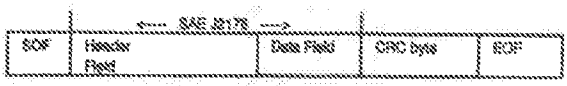


FIGURE 1—SCOPE OF SAE J1278 FOR A SAE J1850 FRAME WITHOUT IN-FRAME RESPONSE (IFR)

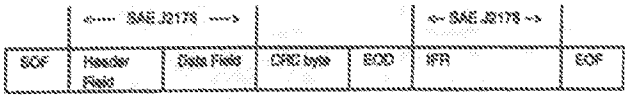


FIGURE 2—SCOPE OF SAE J2178 FOR A SAE J1850 FRAME WITH IN-FRAME RESPONSE (IFR)

SAE J1850 defines two and only two formats of message headers. They are the Single Byte header format and the Consolidated header format. The Consolidated header format has two forms, a Single Byte form and a three byte form. This document covers all of these formats and forms to identify the contents of messages which could be sent on a SAE J1850 network.

This document consists of four parts, each published separately.

SAE J2178/1 (Titled: Detailed Header Formats and Physical Address Assignments) describes the two allowed forms of message header formats, single byte and consolidated. It also contains the physical node address range assignments for the typical sub-systems of an automobile.

SAE J2178/2 (Titled: Data Parameter Definitions) defines the standard parametric data which may be exchanged on SAE J1850 (Class B) networks. The parameter scaling, ranges, and transfer functions are specified. Messages that refer to these parametric definitions shall always adhere to these parametric definitions. It is intended that at least one of the definitions for each parameter in this part match the SAE J1979 definition.

SAE J2178/3 (Titled: Frame IDs for Single Byte Forms of Headers) defines the message assignments for the single byte header format and the one byte form of the consolidated header format.

SAE J2178/4 (this part, Titled: Message Definition for Three Byte Headers) defines the message assignments for the three byte form of the consolidated header format.

2. *References*

2.1 Related Publications—The following publications are provided for information purposes only and are not a required part of this document.

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

SAE J1213/1 JUN91—Glossary of Vehicle Networks for Multiplex and Data Communications

SAE J1850 AUG91—Class B Data Communication Network Interface

SAE J1930 SEP91—Electrical/Electronic Systems Diagnostic Terms, Definitions, Abbreviations, and Acronyms

SAE J1979 DEC91—E/E Diagnostic Test Modes

SAE J2190 JUN93—Enhanced E/E Diagnostic Test Modes

Page 736 of 1656 OMEGA EXHIBIT 2037

2.1.2 ANSI Publication---Available from ANSI, 11 West 42nd Street, New York, NY 10036-8002.

ANSI/IEEE Std 754-1985, August 12, 1985---IEEE Standard for Binary Floating-Point Arithmetic

2.2 Abbreviations and Acronyms

A/C - Air Conditioning
ASC - ASCII Encoded SLOT
BCD - Binary Coded Decimal (BCD) SLOT
BMM - Bit Mapped with Mask SLOT
BMP - Bit Mapped without Mask SLOT
CRC - Cyclic Redundancy Check
CS - Checksum
DTC - Diagnostic Trouble Code
EOD - End of Data
EOF - End of Frame
ERR - Error Detection
HVAC - Heating, Ventilation, Air Conditioning
ID - Identifier
IFR - In-Frame Response
LSB - Least Significant Bit / Byte
MSB - Most Significant Bit / Byte
NB - Normalization Bit
PID - Parameter IDentification (number, NOT the primary ID, See Section 7)
PKT - Multiple Parameter Packet SLOT
PRN - Parameter Reference Number
SED - State Encoded SLOT
SFP - Signed Floating Point (Scientific Notation) SLOT
SLOT - Scaling, Limit, Offset, and Transfer Function (See Section 8)
SNM - 2's Complement Signed Numeric SLOT
SOF - Start of Frame
UNM - Unsigned Numeric SLOT
VIN - Vehicle Identification Number

3. Terms and Definitions

3.1 Data [Data Field]---Data and data field are used interchangeably in this document and they both refer to a field within a frame that may include bytes with parameters pertaining to the message and/or secondary ID and/or extended addresses and/or test modes which further defines a particular message content being exchanged over the network.

3.2 Extended Address---The extended address is a means to allow a message to be addressed to a specific geographical location or zone of the vehicle, independent of any node's physical address.

3.3 Frame---A frame is one complete transmission of information which may or may not include an In-Frame Response. The frame is enclosed by the start of frame and end of frame symbols. For Class B networks, each frame contains one and only one message (see "message" definition below).

3.4 Frame ID---The Frame ID is the header byte for the Single Byte Header format and the one byte form of the Consolidated header format. The definition of the frame ID is found in SAE J2178/3. This header byte defines the target and source and content of the frame.

3.5 Functional Addressing---Functional addressing allows a message to be addressed or sent to one or more nodes on the network interested in that function. Functional addressing is intended for messages that may be of interest to more than a single node. For example, an exterior lamp "off" message could be sent to all nodes controlling the vehicle exterior lamps by using a functional address. The functional address consists of a primary ID and may include a secondary ID and may also include an extended address.

3.6 Header [Header Field]---The header (or header field, used interchangeably) is a one or three byte field within a frame that contains information about the message priority, message source and target addressing, message type, and in-frame response type.

3.7 In-Frame Response (IFR) Type---The IFR type identifies the form of the in-frame response which is expected within that message.

3.8 Load---The load command indicates the operation of directly replacing the current/existing value of a parameter with the parameter value(s) contained in the message.

3.9 Message---A message consists of all of the bytes of a frame excluding the delimiter symbols (SOF, EOD, EOF, NB).

3.10 Modify---The modify command indicates the operation of using the message data parameter value to change (e.g., increment, decrement, or toggle) the current/existing value.

3.11 Parameter---A parameter is the variable quantity included in some messages. The parameter value, scaling, offset, units, transfer function, etc., are unique to each particular message. (The assigned parameters are contained herein.)

3.12 Physical Addressing---Physical addressing allows a message to be addressed to a specific node or to all nodes or to a non-existent, null node. The information in this message is of relevance only to a particular node, so the other nodes on the bus should ignore the message, except for the case of the "all nodes" address.

3.13 Primary ID---The primary ID identifies the target for this functional message. This is the primary discriminator used to group functions into main categories.

3.14 Priority---The priority describes the rank order and precedence of a message. Based upon the SAE J1850, Class B arbitration process, the message with the highest priority will win arbitration.

3.15 Report---A report indicates the transmission of parametric data values, based on: a change of state; a change of value; on a periodic rate basis; or as a response to a specific request.

3.16 Request---A request is a command to, or a query for data, or action from another node on the network.

3.17 Response Data---The response data is the information from a node on the network in response to a request from another node on the network. This may be an in-frame response or a report type of message.

3.18 Secondary ID---The secondary ID (along with the primary ID or Frame ID) identifies the functional target node for a message. The purpose of the secondary ID field within the frame is to further define the function or action being identified by the primary ID.

4. General Information---The messages defined by this four part document are specified for networks using one byte headers or consolidated one and three byte headers as specified in SAE J1850. This part focuses on the message definition for the three byte form of the consolidated header format. Section 5 consists of the list of functional target addresses for all of the functionally addressed SAE J1850 messages except Type #3, Function Read. The SAE J1850 Type #3 messages have a separate address assignment because this message type does not support any secondary addressing. Functional target addresses (Primary IDs) are shown in Section 5 and secondary message definitions are shown in Section 7. Section 6 shows the valid extended address assignments which are referenced in the message definition tables.

The information in the header field contains target, source, priority and message type information, while the data field contains additional addressing and parametric information. This information is explicitly defined in some headers and implicitly defined in others. Messages can be classified generally into two types:

a. Requests, that is, commands (load or modify) or queries for data, and
b. Responses, that is, reports or acknowledgements.

When a node generates a request, the target node(s) which is/are responsible for the requested data or function must respond by sending the requested information or by performing the requested function. For responses (that is, reports or acknowledgements), data information that a node responds with may be requested by another node, or reported by the node when the desired information has changed, or reported by the node on a periodic basis.

This document defines a great number of specific messages which are expected to have wide application. Designers are required to use the defined messages on SAE J1850 networks in the exact way that they are defined here. There are a large number of message codes which are reserved for each manufacturer to define. If the user cannot find a needed message, he or she is expected to define a manufacturer specific message in these reserved codes. Therefore, messages on different manufacturer's products using these "Manufacturer Reserved" codes will have meaning only for that manufacturer or specific vehicle. These will most likely be different between manufacturers. The codes that are defined here, however, shall always carry the same meaning from one manufacturer to another and from one model and year to the next.

5. Functional Target Address Assignments (Primary ID)---Primary IDs are used to address a generic function. The second byte of the three byte header contains this primary ID. Each target function has a separate ID for command and status messages. The command ID is used to control a function while the status ID is used to report a condition or report that a command has been executed. Each primary ID pair then contains a secondary address, optional geographical extended address, and optional parametric data. Table 1 below lists the primary ID assignments, command and status, and a description. Those IDs labeled as "Reserved - SAE" are reserved for the SAE to define at a later time while those labeled "Reserved - MFG" are left for the individual manufacturers to use.

Page 737 of 1656 OMEGA EXHIBIT 2037