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SURFACE VEHICLE INFORMATION REPORT

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E/E Diagnostic Data Communications

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1. ***Scope***—This SAE Information Report describes the diagnostic data communications required for implementation of a set of diagnostic test modes for all electronic systems on the vehicle's serial data link. These test modes can be used by off-board test equipment for both service and assembly plant testing.

The goal of this document is to provide standard methods to perform common functions for all electronic systems. This standard set of procedures will aid development, production, and field service of those systems. Use of the standard data communications in this specification will potentially result in the following benefits:

Common methods and procedures for developers to use, without the need to invent methods to perform these functions
Common programming techniques for system programmers, with increased sharing of software procedures
Common hardware, software and test procedures for assembly plant testing
Common hardware, software and service procedures for service diagnostics across different vehicle manufacturers and systems

This specification includes:

Diagnostic Message Formats
Device ID's
Functional descriptions of all diagnostic test modes
Message and response formats for all diagnostic test modes

1.1 Purpose—The diagnostic test modes (DTM) provide off-board test equipment with communication access to the on-board vehicle electronic systems. The off-board equipment shall be able to interrogate the electronic systems on the vehicle, and exercise control over these systems for the purposes of verifying system operation and diagnosing malfunction conditions.

Diagnostic test modes are predefined and standardized for all systems on the vehicle. Each device on the vehicle will implement only those DTMs which are appropriate for that device. Not all modes will be implemented on each device. If use of these modes is not appropriate for a given application, or during some operating modes, then that device is responsible to verify safe and proper operation and not respond to the request.

2. ***References***

2.1 Applicable Publications—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 Dr., Warrendale, PA 15096-0001.

SAE J1850—Class B Data Communication Network Interface
SAE J2037—Off-Board Diagnostic Message Formats
SAE J2062—A Class B Serial Bus Diagnostic Protocol
SAE J2086—An Application Layer Protocol for a Generic Scan Tool

3. ***Diagnostic Message Summary***—This specification defines 14 Diagnostic Test Modes.

Mode 0—Return to Normal Mode
Mode 1—Transmit Diagnostic Data
Mode 2—Memory Dump
Mode 3—Examine RAM Memory
Mode 4—Device Control Functions
Mode 5—RAM Download Request
Mode 6—RAM Download and Execute
Mode 7—Command Normal Message
Mode 8—Disable Normal Communications
Mode 9—Enable Normal Communications
Mode 10—Clear Malfunction Codes
Mode 11—Suspend Normal Message
Mode 12—Define Diagnostic Message by Data Position
Mode 13—Define Diagnostic Message by Memory Address

4. ***Diagnostic Test Mode General Message Format***—DTM messages all conform to the following general format:

BYTE	DESCRIPTION
1	Priority—first 4 bits Message Length—second 4 bits
2	Device ID for Target
3	Device ID for Source
4	Message type/format—first 4 bits Diagnostic Mode Number—second 4 bits

The first byte of the message is a combination of priority (4 bits) and message length (4 bits). Message length is used as one check for data integrity. This also allows shorter messages with the same priority as longer messages to be transmitted first, which can improve the efficiency of the data link.

Each device will be assigned an ID unique to that device. The second byte of all DTM messages is the Device ID for the intended receiver of the message, and the third byte is the Device ID for the source of the message.

The fourth byte contains a combination of Message type / format (4 bits) and diagnostic mode number (4 bits). Various types of messages will be defined for normal mode communications and for diagnostic modes. This value indicates the structure for the remaining bytes of the message. The mode number indicates the action the device shall take in response to the message. Those actions are defined in the functional description section for each mode.

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. Those elements are:

Start of Message (SOM)
Error Detection Byte (ERR)
End of Data (EOD)
Response Byte(s) (RSP)
End of Message (EOM)
Inter-Message Separation (IMS)
Inter-Byte Separation (IBS)

5. ***Device IDs***—A unique device ID should be assigned for each type of electronic system that will be used on different vehicles (see Table 1). Wherever possible, those codes should remain constant for that type of device on all vehicles. This will enable that same device to be utilized on other vehicles without software modifications to alter the device code. If those codes are unique, it will also eliminate any message conflict with other devices trying to use the same device code.

Device ID $FF applies to all devices on the serial data link. This ID can be used to send the same request to all devices on the vehicle for purposes such as retrieving malfunction codes, disabling normal communications, or returning all devices to normal operation. All devices on the data link should then respond to this request with a response that includes their unique device ID. This enables the test device to determine which devices are on the data link and able to communicate.

TABLE 1—ASSIGNED DEVICE ID'S
(ALL IDS SHOWN IN HEX NOTATION)

Device ID	Device/Function
FF	All Devices
F0	DTM Test Device
F1	Body/Central Control Module
F2	Primary Display Device
F3	Secondary Display Device
F4	Engine Control
F5	Transmission Control
F6	Compass
E6	Engine Oil Life Monitor
F7	Ride Control
F8	Steering Control
F9	Brake/Traction Control
FA	Supplemental Inflatable Restraint
EA	HVAC Control
FB	Audio Warning (Voice Module/Chime)
EB	Remote Accessory Control
FC	Throttle Control
EC	Calculator
FD	Cellular Phone
ED	Memory Seat/Mirror

6. ***Diagnostic Test Mode General Conditions***—If any on-board device is in a requested diagnostic mode, and if there is no other diagnostic message on the data link for a period of more than 5 s, that device shall terminate any active diagnostic mode and resume normal system operation. This solves the condition of a test device requesting a nonnormal mode of operation for a device and then disconnecting from the vehicle without returning operation of on-board devices to normal operation. If there is any diagnostic activity on the serial data link, then the on-board devices should assume that the test device may be controlling operation of some or all systems, and should remain in the present state of operation until instructed to change.

Diagnostic mode operation requires that test equipment be aware of previously requested modes, and accommodate for any desired changes. The automatic return to normal also requires that a test device transmit a diagnostic message at least once every 5 s if it needs to prevent on-board devices from returning to normal operation. That message does not need to be directed at any particular device on the link.

The potential exists in response messages for the contents of a multibyte variable to change after the first byte is sent, but before the last byte is sent, resulting in bad data. To maintain data integrity under this condition, hardware or software provisions must be included in each application to ensure that all bytes of multibyte variables are read simultaneously.

7. Diagnostic Test Mode Functional Description

7.1 Mode 0—Return to Normal Mode

7.1.1 FUNCTIONAL DESCRIPTION—The on-board device will return to the normal mode of operation when this command is received. All normal algorithms and normal communications will be resumed.

7.1.2 MODE 0 REQUEST

BYTE	DESCRIPTION
1-4	Message Header (includes Mode = 0)

7.1.3 MODE 0 RESPONSE

BYTE	DESCRIPTION
1-4	Message Header (includes Mode = 0)

7.2 Mode 1—Transmit Diagnostic Data

7.2.1 FUNCTIONAL DESCRIPTION—The on-board device will respond to this message by transmitting from 1 to 8 requested diagnostic data messages specific to that device. The message number bytes in the request allow multiple Mode 1 messages to be requested. Up to 32 messages can be defined for each device. These can either be predefined or defined during the diagnostic procedure using Mode 12 or 13. Messages should be defined with group data that is commonly used together or changes together.

Uses for these different messages 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 messages 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.

7.2.2 MODE 1 REQUEST

BYTE	DESCRIPTION
1-4	Message Header (includes Mode = 0)
5	Transmit Message #1
6	Transmit Message #2 - Optional
7	Transmit Message #3 - Optional
8	Transmit Message #4 - Optional
9	Transmit Message #5 - Optional
10	Transmit Message #6 - Optional
11	Transmit Message #7 - Optional
12	Transmit Message #8 - Optional

Message number is in the range from $00 to $1F.

7.2.3 MODE 1 RESPONSE

BYTE	DESCRIPTION
1-4	Message Header (includes Mode = 1)
5	Message Number
6	Data Byte #1
7	Data Byte #2—Optional
8	Data Byte #3—Optional
9	Data Byte #4—Optional
10	Data Byte #5—Optional
11	Data Byte #6—Optional
12	Data Byte #7—Optional
13	Data Byte #8—Optional

Message number is in the range from $00 to $1F.

7.3 Mode 2—Memory Dump

7.3.1 FUNCTIONAL DESCRIPTION—The on-board device will respond to this message by transmitting the contents of eight memory locations beginning at the address specified in the request.

When using this mode to request data from EEPROM, data integrity will require that the software include provisions to either ensure that the controller is not writing to EEPROM, or that allows extra time for a response to this request. This is necessary because EEPROM cannot be read while a write to EEPROM is in progress.

7.3.2 MODE 2 REQUEST

BYTE	DESCRIPTION
1-4	Message Header (includes Mode = 2)
5	Address 1 (High Order Byte)
6	Address 1 (Low Order Byte)

7.3.3 MODE 2 RESPONSE

BYTE	DESCRIPTION
1-4	Message Header (includes Mode = 2)
5	Address #1 Contents
.	.
.	.
.	.
12	Address #8 Contents

7.4 Mode 3—Examine Memory

7.4.1 FUNCTIONAL DESCRIPTION—The on-board device will respond to this message by transmitting the contents of the memory locations requested by the test device.

The test equipment will include up to four independent two-byte memory addresses in the Request. The addressed device will respond with the one byte contents for each specified address.

When using this mode to request data from EEPROM, data integrity will require that the software include provisions to either ensure that the controller is not writing to EEPROM, or that allows extra time for a response to this request. This is necessary because EEPROM cannot be read while a write to EEPROM is in progress.

7.4.2 MODE 3 REQUEST

BYTE	DESCRIPTION
1-4	Message Header (includes Mode = 3)
5	Address #1 (High Order Byte)
6	Address #1 (Low Order Byte)
7	Address #2 (High Order Byte)—Optional
8	Address #2 (Low Order Byte)—Optional
9	Address #3 (High Order Byte)—Optional
10	Address #3 (Low Order Byte)—Optional
11	Address #4 (High Order Byte)—Optional
12	Address #4 (Low Order Byte)—Optional

7.4.3 MODE 3 RESPONSE

BYTE	DESCRIPTION
1-4	Message Header (includes Mode = 3)
5	Address #1 Contents
6	Address #2 Contents—Optional
7	Address #3 Contents—Optional
8	Address #4 Contents—Optional

7.5 Mode 4—Device Control Functions

7.5.1 FUNCTIONAL DESCRIPTION—The device control function mode provides the ability to define a totally device dependent set of functions. This is a general purpose mode used to communicate those messages which are unique to each device.

The test device will transmit a message to the selected device which may be used to temporarily alter software flags and status words, supply input values, or to exercise displays and outputs. The operation of the device control function mode may be restricted in order to ensure safe operation of the vehicle and to prevent equipment damage.

After a Mode 4 message is issued to change the system condition, other mode messages may be used to observe the effect of the changes.

If any device has received a Mode 4 command and has modified normal operation, and if there is no DTM message directed to any device, other than an FO device request, for a period of more than 5 s, that device shall terminate the Mode 4 and resume normal operation.

7.5.2 MODE 4 REQUEST

BYTE	DESCRIPTION
1-4	Message Header (includes Mode = 4)
5	Data/Control Byte #1
.	.
.	.
.	.
N+4	Data/Control Byte #N

where:

N = Number of Data/Control bytes must be in the range from 1 to 8.

7.5.3 MODE 4 RESPONSE

BYTE	DESCRIPTION
1-4	Message Header (includes Mode = 4)
5	Data/Status Byte #1—Optional
.	.
.	.
.	.
N+4	Data/Status Byte #N

where:

N = Number of Data/Status bytes must be in the range from 0 to 8.

The minimum response is three header bytes plus the message type / mode number.

7.6 Mode 5—Ram Download Request

7.6.1 FUNCTIONAL DESCRIPTION—The purpose of this message is to allow a test device to request an on-board device to prepare to receive executable code via the serial data link. The test device can be either an on-board device or an off-board test device.

The download request message includes the starting address to store the code to be downloaded and the number of bytes of code to be downloaded. This allows the on-board device to reject the request if that memory location is not acceptable.

This request gives the on-board device the necessary time to safely exit normal operations and prepare to receive data. Also, the on-board device can refuse the request if certain conditions are not satisfied due to other operations. The conditions required to allow or disallow a download will be dependent upon the on-board system, and are application dependent. Usually systems necessary for safe vehicle operation will not allow a download because of the possibility that the downloaded code could cause improper system operation.

Once a positive response has been sent by the on-board device, it will wait for a Message 6 from the tester to download code. A second Mode 5 command may be sent to the controller in the case of a garbled acceptance to the tester. The controller should always accept additional Mode 5 requests if currently waiting for a Mode 6 command. Other messages on the data link are allowed for other devices, but the on-board device will return to normal operation if a message is received for that device that is not a Mode 5 or Mode 6. The controller will also return to normal operation if there is no diagnostic test message on the data link for a period of 5 s.

Some systems will execute a monitor program after accepting the Mode 5 request. During the monitor program, normal software routines will not be executed, and the system may not be updated to allow normal operation. Some provision needs to be made to ensure that the system will operate normally after exiting from this monitor. This precaution may require a system reset to return to a known condition.

7.6.2 MODE 5 REQUEST

BYTE	DESCRIPTION
1-4	Message Header (includes Mode = 5)
5	Starting Address (High Byte)
6	Starting Address (Low Byte)
7	Number of bytes to be downloaded

7.6.3 MODE 5 RESPONSE

BYTE	DESCRIPTION
1-4	Message Header (includes Mode = 5)
5	Response Data—Accept = $AA Reject = any other response

7.7 Mode 6—RAM Download and Execute

7.7.1 FUNCTIONAL DESCRIPTION—The RAM Download and Execute message will always follow a RAM Download Request Message 5. The device receiving the message must verify that it can accept a download. This requires that the on-board device has responded to a Message 5 request and is now ready to accept code. If this condition has not been met, the on-board device should ignore the download message.

The on-board device will store the code at the address specified in the Mode 5 request message from the test device. At the end of this message, the onboard device should begin executing code at that starting address.

Normally data will be sent back to the test device during program execution. Multiple messages may be returned to the tester, depending on device specific criteria. If this is the case, then one of the data bytes should be used to distinguish between the possible messages. If messages are returned to the tester, then those messages should conform to the general format used in this document.

At the completion of the program, some provision needs to be made to return the operation of the device to normal. One possible action is for the on-board device to send a final Message 6 response indicating the end of the program, and then execute a Reset. Some systems will return back to a Mode 5 monitor program and wait for another Mode 6. In this case, care must be taken to ensure normal operation of the system after the return from the Mode 5 routine. In some applications, it may be necessary for the technician to power down the system and then turn power back on for the device to operate normally. The main caution to be observed is that while in the Mode 6 routine, the downloaded program has total control of registers and memory, and the controller must be returned to a known condition, which is most easily accomplished with a Reset.

Because of the wide variety of possible uses for this mode, and the wide variety of device hardware, a standard means cannot be specified to always return to normal operation. The caution is noted here only to ensure that this requirement is not overlooked.

This mode requires a block transfer mode that allows transmission of messages which are approximately 128 to 256 bytes long. These are considered special case modes which would not be used for standard diagnostics, but are required for assembly line testing and complex service procedures performed by high function diagnostic equipment.

7.7.2 MODE 6 REQUEST

BYTE	DESCRIPTION
1-4	Message Header (includes Mode = 6)
5	First byte of code
	.
	.
	.
N+4	Nth byte of code

where:

N = Number of bytes of code to be downloaded.
Must be in the range from 1 to 128 (256?).

This mode requires a block transfer mode.

7.7.3 MODE 6 RESPONSE (OPTIONAL)

BYTE	DESCRIPTION
1-4	Message Header (includes Mode = 6)
5	Data Byte #1—Optional
	.
	.
	.
N+4	Data Byte #N

where:

N = Number of Data Bytes to be returned.
Must be in the range from 0 to 8.

A Mode 6 response is optional, depending on the application.

7.8 Mode 7—Transmit Normal Message

7.8.1 FUNCTIONAL DESCRIPTION—The purpose of this mode is to allow the test equipment to request from 1 to 4 specific normal mode messages to be transmitted by the on-board device. The on-board device will respond to this message by transmitting the requested messages. The requested message will be the only response from the on-board device. This mode is usually only applicable if a previous Mode 8 command has suspended all normal communications.

7.8.2 MODE 7 REQUEST

BYTE	DESCRIPTION
1-4	Message Header (includes Mode = 7)
5-6	Transmit Message #1
7-8	Transmit Message #2 (Optional)
9-10	Transmit Message #3 (Optional)
11-12	Transmit Message #4 (Optional)

1 to 4 normal mode messages can be requested.

7.8.3 MODE 7 RESPONSE—Normal mode messages specified in the Mode 7 Request are transmitted.

7.9 Mode 8—Disable Normal Communications

7.9.1 FUNCTIONAL DESCRIPTION—The purpose of this mode is to inhibit the on-board device from transmitting data on the link while still performing other functions normally. The device will continue to operate in whatever conditions were set by a previous Mode 4 command.

One use of this mode is to allow the test equipment to emulate the on-board device for diagnostic purposes. In this scenario, the test device would send a Mode 8 Request to the device to be emulated. The test device would then respond with all normal communication messages transmitted by 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 those systems.

If any device has received a Mode 8 command and has suspended normal communications, and if there is no diagnostic test message for a period of more than 5 s, that device shall terminate the Mode 8 and resume normal operations.

7.9.2 MODE 8 REQUEST

BYTE	DESCRIPTION
1-4	Message Header (includes Mode = 8)

7.9.3 MODE 8 RESPONSE

BYTE	DESCRIPTION
1-4	Message Header (includes Mode = 8)

7.10 Mode 9—Enable Normal Communications

7.10.1 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 8 command. The device will continue to operate in whatever conditions were set by a previous Mode 4 command.

7.10.2 MODE 9 REQUEST

BYTE	DESCRIPTION
1-4	Message Header (includes Mode = 9)

7.10.3 MODE 9 RESPONSE

BYTE	DESCRIPTION
1-4	Message header (includes Mode = 9)

7.11 Mode 10—Clear Malfunction Codes

7.11.1 FUNCTIONAL DESCRIPTION—The purpose of this mode is to provide a means for the external test device to command an on-board device to clear all malfunction codes.

7.11.2 MODE 10 REQUEST

BYTE	DESCRIPTION
1-4	Message Header (includes Mode = 10)

7.11.3 MODE 10 RESPONSE

BYTE	DESCRIPTION
1-4	Message Header (includes Mode = 10)

7.12 Mode 11—Suspend Normal Message

7.12.1 FUNCTIONAL DESCRIPTION—The purpose of this mode is to provide a means for the external test device to command the on-board communications scheduler to suspend some normal mode communications message.

The increased data communications required for diagnostics may require very high utilization of the serial data link. In order to allow time for the desired messages, this test mode is included to suspend scheduling of selected normal messages which use significant amounts of link time and are unnecessary during diagnostics. The test device sends a list of the messages to suspend.

When a mode 11 message is received, any normal messages previously suspended, but not included in the list of messages to suspend, should be scheduled for transmission. Each Mode 11 message can, therefore, be considered as a complete list of the messages to suspend. This will allow both disabling some messages and enabling others with a single message to the on-board device. All normal messages can be transmitted by sending a Mode 11 with no messages to suspend.