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SURFACE VEHICLE INFORMATION REPORT

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Serial Data Communication Interface

***Foreword*—**The purpose of this document is to specify the requirements necessary to fully define the Serial Data Communication Interface (SCI) used in the reprogramming of emission-related powertrain Electronic Control Units (ECU) in DaimlerChrysler Corporation (Chrysler Group) vehicles. It is intended to satisfy new regulations proposed by the federal U.S. Environmental Protection Agency (EPA) and California Air Resource Board (CARB) regulatory agencies regarding “pass-thru programming” of all On-Board Diagnostic (OBD) compliant emission-related powertrain devices. These requirements are intended to provide independent automotive service organizations and after-market scan tool suppliers the ability to reprogram emission-related powertrain ECUs for all manufacturers of automotive vehicles.

This specification shall strictly apply to DaimlerChrysler Corporation vehicles developed and manufactured exclusively by the former Chrysler Corporation, and for purposes of clarification, referred to herein as DaimlerChrysler Corporation (Chrysler Group). This specification shall not apply to other DaimlerChrysler Corporation vehicles or subsidiaries, including products developed and manufactured by Mercedes-Benz, Smart, or Mitsubishi Motors Corporation. The SCI communication link defined herein shall apply to OBD vehicles retroactive to the 1994 model year. These requirements are in addition to the approved OBD communication links previously specified and included in SAE J2534 Pass-Thru Programming, and constitute unique DaimlerChrysler Corporation (Chrysler Group) manufacturer-specific requirements. This specification will be referenced from within SAE J2534 as a technical information report.

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1. Scope

1.1 **Purpose—**The purpose of this SAE Information Report is to specify the requirements necessary to fully define the Serial Data Communication Interface (SCI) used in the reprogramming of emission-related powertrain Electronic Control Units (ECU) in DaimlerChrysler Corporation (Chrysler Group) vehicles. It is intended to satisfy new regulations proposed by the federal U.S. Environmental Protection Agency (EPA) and California Air Resource Board (CARB) regulatory agencies regarding “pass-thru programming” of all On-Board Diagnostic (OBD) compliant emission-related powertrain devices. These requirements are necessary to provide independent automotive service organizations and after-market scan tool suppliers the ability to reprogram emission-related powertrain ECUs for all manufacturers of automotive vehicles.

Specifically, this document details the SCI physical layer and SCI data link layer requirements necessary to establish communications between a diagnostic tester and an ECU. It further specifies additional requirements for the application of a flash strobe voltage multiplexed on the SCI communication link for purposes of ECU reprogramming. This document does not specify the content or meaning of the application messages or diagnostic protocol to be transmitted on the SCI communication link. It only defines a generic method to transfer data between a diagnostic tester and an ECU, regardless of application messaging structure.

This specification will be referenced from within SAE J2534 Pass-Thru Programming as a technical information report. In this regard, the inclusion of the SCI communication link is in addition to the approved OBD communication links previously specified in SAE J2534, and constitutes unique DaimlerChrysler Corporation (Chrysler Group) manufacturer-specific requirements.

1.2 **Applications—**This document shall strictly apply to DaimlerChrysler Corporation vehicles developed and manufactured exclusively by the former Chrysler Corporation, and for purposes of clarification, referred to herein as DaimlerChrysler Corporation (Chrysler Group). This document shall not apply to other DaimlerChrysler Corporation vehicles or subsidiaries, including products developed and manufactured by Mercedes-Benz, Smart, or Mitsubishi Motors Corporation. The SCI communication link defined herein shall apply to OBD vehicles retroactive to the 1994 model year.

1.3 **History—**DaimlerChrysler Corporation (Chrysler Group) introduced flash technology into emission-related powertrain ECUs beginning in the 1993 model year. Flash technology consisted of implementing reprogrammable memory devices into powertrain ECUs for purposes of updating software functionality and calibrations in the customer field (service environment), assembly plant (manufacturing environment), and vehicle development (engineering environment). Reprogramming events in the field require strict compliance to corporate guidelines based on the following criteria:

Vehicle performance / driveability
Vehicle safety
Vehicle emissions
Vehicle fuel economy
Customer satisfaction

The DaimlerChrysler Corporation (Chrysler Group) corporate flash strategy consists of incorporating proprietary standards and requirements into the flash process. These requirements involve the integration of multiple levels of protective security measures using software and hardware lockout techniques including additional safeguard mechanisms controlled via internal corporate processes and corporate test tools. New regulations will force a change in the current DaimlerChrysler Corporation (Chrysler Group) flash strategy and process.

2. References

2.1 Applicable Publications—The following publications form a part of this specification to the extent specified herein. Unless otherwise specified, the latest issue of publications shall apply.

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

SAE J1850—Class B Data Communications Network Interface
SAE J1962—Diagnostic Connector
SAE J1979—E/E Diagnostic Test Modes
SAE J2190—Enhanced E/E Diagnostic Test Modes
SAE J2534—Pass-Thru Programming

2.1.2 ISO PUBLICATIONS—Available from ANSI, 25 West 43rd Street, New York, NY 10036-8002.

ISO 9141-2—Road vehicles—Diagnostic systems—Part 2: CARB requirements for interchange of digital information
ISO 14230-4—Road vehicles—Keyword protocol 2000 for diagnostic systems—Part 4: Requirements for emission-related systems
ISO 15765-4—Road vehicles—Diagnostics on CAN—Part 4: Requirements for emission-related systems

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

2.2.1 CHRYSLER GROUP PUBLICATIONS—Available from DaimlerChrysler Corporation, Vehicle Diagnostics, CIMS 484-08-06, 800 Chrysler Drive, Auburn Hills, MI USA 48326-2757.

SCI Diagnostic Protocol for PCM Applications, DaimlerChrysler Corporation (Chrysler Group)
SAE J2190 Diagnostic Protocol for PCM Applications, DaimlerChrysler Corporation (Chrysler Group)
System and Method for Reprogramming Vehicle Computers, U.S. Patent No. 5,278,759, DaimlerChrysler Corporation (Chrysler Group)

2.2.2 MOTOROLA, INC., PUBLICATION—Available from Motorola Literature Distribution, P.O. Box 20912, Phoenix, AZ USA 85036.

Queued Serial Module (QSM) Reference Manual, Motorola, Inc.

3. Definitions

3.1 Bit—The contraction of binary digit representing the smallest unit of information. A bit can assume either a logical high (e.g., mark) or logical low (e.g., space) value.

3.2 Bit Time—The time required to serially transmit/receive one bit of data, which is equal to one cycle of the baud frequency.

3.3 Break—A character or symbol used to terminate bus communications and reset all nodes to a ready-to-receive state.

3.4 Character—A data byte contained in a data frame transmission.

3.5 Frame—One complete transmission of information delineated by the start of frame (start bit) and end of frame (stop bit) identifiers.

3.6 Message—An orderly sequence of data frame transmissions having varying length.

3.7 **Full-Duplex—**A communication system capable of simultaneous bi-directional communications.

3.8 **Half-Duplex—**A communication system capable of bi-directional communications, but only in one direction at a time.

3.9 **Mark—**A state of a binary element indicating a logical high or "1" value (inverse of space).

3.10 **Space—**A state of a binary element indicating a logical low or "0" value (inverse of mark).

3.11 **Start Bit—**The first binary element transmitted in the asynchronous transmission of a data frame. It is used to uniquely identify the beginning of a data frame transmission to synchronize the receiver to an active session.

3.12 **Stop Bit—**The last binary element transmitted in the asynchronous transmission of a data frame. It is used to uniquely identify the end of a data frame transmission to return the receiver to an idle condition.

4. Abbreviations and Acronyms

bps – bits per second
BRK – Break
CAN – Controller Area Network
CARB – California Air Resource Board
ECM – Engine Control Module
ECU – Electronic Control Unit
EPA – Environmental Protection Agency
ISO – International Standards Organization
LSB – Least Significant Bit
MSB – Most Significant Bit
NRZ – Non-Return-to-Zero
OBD – On-Board Diagnostic
PCM – Powertrain Control Module
PROM – Programmable Read Only Memory
RAM – Random Access Memory
ROM – Read Only Memory
Rx – Receive
SAE – Society of Automotive Engineers
SCI – Serial Communication Interface
TCM – Transmission Control Module
TTL – Transistor-Transistor Logic
Tx – Transmit
UART – Universal Asynchronous Receiver Transmitter

5. Technical Overview

5.1 **General—**The Serial Data Communication Interface (SCI) is defined as a full-duplex, asynchronous, UART-based serial interface for point-to-point communications between an off-board diagnostic tester and an on-board electronic control unit (ECU). The SCI communication link is required to support the diagnosis and reprogramming of emission-related powertrain devices for DaimlerChrysler Corporation (Chrysler Group) vehicles. It is implemented as a non-inverted 0 to 5 V DC asynchronous system requiring a 5 V DC idle high mode. SCI baud rates are software selectable for data transmission modes. SCI terminations at the diagnostic connector must be software selectable for multiplexing old and new SCI configurations. Additionally, the application of a flash strobe voltage multiplexed on the SCI communication link is required for reprogramming ECU memory devices.

The following points summarize the SCI communication link requirements:

a. Full-duplex, dual-wire interface using one Rx line and one Tx line
b. Non-inverted Transistor-Transistor Logic (TTL) voltage level operation using idle "high" mode
c. Non-Return-To-Zero (NRZ) bit-coding format using 10-bit data frame
d. Multiple data rates of 7812.5 bps, 62.5 Kbps, 125.0 Kbps
e. Flash strobe voltage (Vpp) using multiplexed 20 V DC source

5.2 **Communication Model—**The SCI communication model characterizes the SCI communication behavior into three conceptual layers: SCI Physical Layer, SCI Data Link Layer, and Message Application Layer. In this regard, SCI communications is accomplished through the conceptual layering of peer entities. Each peer entity forms a virtual communication link. The layers allow transmitted data bits to be grouped into data frames, data frames constructed into messages, and messages mapped into application-specific protocol functions. This is illustrated in the SCI communication model in Figure 1:

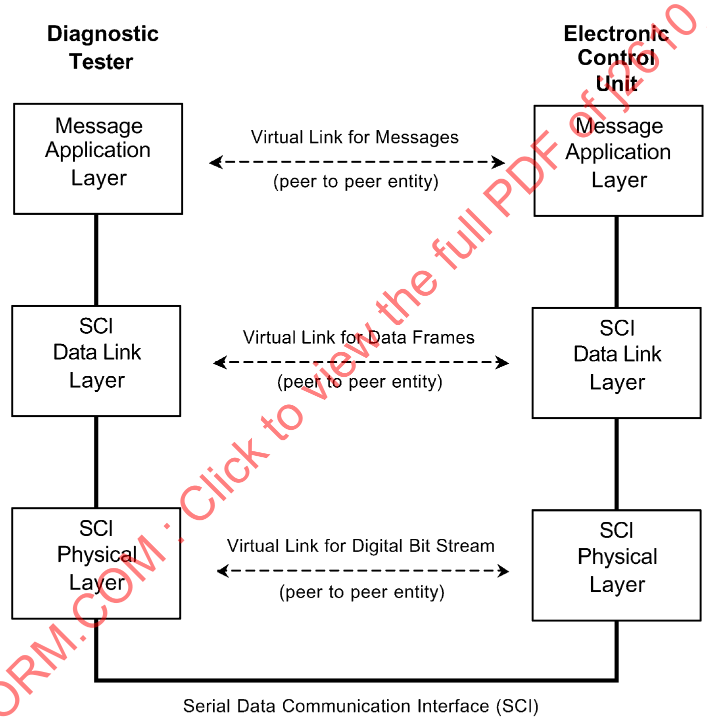


FIGURE 1—SCI COMMUNICATION MODEL DEPICTING THE THREE CONCEPTUAL LAYERS

Note that the SCI communication model does not specify the content or meaning of the application messages or diagnostic protocol to be transmitted on this interface. It only defines a generic method to transfer data between a diagnostic tester and an ECU, regardless of application messaging structure.

6. ***Physical Layer—***The SCI Physical Layer is responsible for transferring data bits between the diagnostic tester and the ECU. The SCI Physical Layer defines the data transmission rates, electrical signals, physical media, routing, and connectivity to the vehicle.

6.1 Data Rate Specification—The SCI communication link shall have a default data rate of 7812.5 bps. A communication session between a diagnostic tester and an ECU shall always be initiated at the default data rate. A change in data rate can be negotiated once communications are established between the diagnostic tester and ECU. The ECU shall automatically track to the requested data rate following a command sequence from the diagnostic tester. The command sequence is initiated by transmitting a specific training character to the ECU. The ECU shall respond with an acknowledgement character following establishment of the proper data rate. For proper operation of serial communications, the diagnostic tester and ECU shall support the data rates as specified in Figure 2.

Description	**Data Rate** (bits per second)	**Bit Time** (microseconds)	**Tolerance** (%)
Low-Speed Mode (Default)	7812.5	128.0	+/- 2.0
High-Speed Mode 1	62.5 K	16.0	+/- 2.0
High-Speed Mode 2	125.0 K	8.0	+/- 2.0

FIGURE 2—SCI COMMUNICATION MODES WITH AVAILABLE DATA RATES AND BIT TIMES

The bit time is the time required to serially transmit/receive one bit of data. It is equal to one cycle of the baud frequency as determined by the selected data rate.

6.1.1 INITIALIZATION—An ECU shall always initialize to the default low-speed communication rate of 7812.5 bps following an ECU power-on or reset condition.

6.1.2 COMMUNICATION MODES—An ECU shall support the following communication modes of operation:

a. Low-Speed Mode—The low-speed mode shall be used for initializing a communication exchange or diagnostic session between a diagnostic tester and an ECU.
b. High-Speed Mode—The high-speed mode(s) shall be used for establishing a data acquisition session or flash reprogramming download session between a diagnostic tester and an ECU.

6.2 Signal Definition—For proper operation of serial communications, the diagnostic tester and ECU shall correctly determine each signal value as specified as follows.

6.2.1 LOGIC LEVELS—A standard Non-Return-to-Zero (NRZ) bit-coding format shall be required using non-inverted Transistor-Transistor Logic (TTL) voltage levels. The logic states of each binary element are defined as follows:

a. Logic “1” State: A logic “1” state (high) shall be equivalent to a voltage level greater than 4.0 V (i.e., 80% of Vdd).
b. Logic “0” State: A logic “0” state (low) shall be equivalent to a voltage level less than 1.0 V (i.e., 20% of Vdd).

The rise and fall times shall be less than 10% of the bit times specified by the data rate. The rise and fall times shall be defined as the time for the voltage to change from 20% to 80% of Vdd (rise time), and from 80% to 20% of Vdd (fall time). This implies that in the 7812.5 bps low-speed mode, the rise time from 1.0 V to 4.0 V shall be no longer than 12.8 microseconds. In the 62.5 Kbps and 125.0 Kbps high-speed modes, rise and fall times shall be no longer than 1.6 microseconds and 0.8 microseconds, respectively.

6.2.2 IDLE CONDITION—An idle condition shall be defined as 10 (or more) consecutive bit times at a logic “1” state. Hence, the SCI communication link shall enter a “bus high” state when an idle condition is declared.

6.2.3 BREAK CONDITION—A break condition shall be defined as 10 (or more) consecutive bit times at a logic “0” state (i.e., BRK character). The BRK character is used to terminate bus communications and reset all nodes to a ready-to-receive state. Hence, the SCI communication link shall enter a “bus low” state when a break condition is declared.

6.3 Routing and Connectivity—Connectivity from the diagnostic tester to the vehicle shall be provided via the SAE J1962 Diagnostic Connector. Physical routing from the diagnostic connector to each ECU shall be provided via an SCI receive/transmit communication link in accordance to the specifications as follows.

6.3.1 DIAGNOSTIC CONNECTOR CONFIGURATIONS—The SAE J1962 Diagnostic Connector is an industry-standard 16-pin common connector configuration defined for use in automotive vehicles. The diagnostic connector provides the physical means by which access to the on-board vehicle communication network is accomplished. The specific assignment and functionality of a fixed set of connector terminals has been defined by SAE for common industry-standard use by all vehicle manufacturers. The remaining undefined connector terminals are allocated for manufacturer-specific use for unique applications.

A revision to the SAE J1962 Diagnostic Connector recommended practice was enacted due to new regulations allowing provisions for the acceptance of a Controller Area Network (CAN) as a viable alternative On-Board Diagnostic (OBD) communication interface. Consequently, new SAE requirements redefined connector pins 6 and 14, previously designated as manufacturer-specific, as SAE-specific for the development and integration of CAN. DaimlerChrysler Corporation (Chrysler Group) had previously designated pins 6 and 14 as SCI receive lines for the engine ECU and transmission ECU, respectively. Consequently, DaimlerChrysler Corporation (Chrysler Group) has defined two unique connector configurations for use in vehicle applications. Configuration 'A' shall be referred to as the 'old' configuration, and Configuration 'B' shall be referred to as the 'new' configuration. Each connector configuration is defined in the following sections.

a. Configuration 'A'—Configuration 'A' shall be used in DaimlerChrysler Corporation (Chrysler Group) vehicles beginning in the 1994 model year through the 2001 model year, and shall gradually be replaced beginning in the 2002 model year by Configuration 'B'. Physical routing to ECUs shall be handled by providing a separate SCI receive line to each ECU. The engine ECU shall support an SCI receive line terminated at pin 6, and the transmission ECU shall support an SCI receive line terminated at pin 14. Both engine and transmission ECUs shall share a common SCI transmit line terminated at pin 7 (wire-ORed together). SCI connections to pins 6 and 14 shall not electrically interfere with ISO15765-4 CAN operation. Likewise, SCI connections to pin 7 shall not electrically interfere with ISO9141-2 operations. Additionally, if a vehicle supports SAE J1979 legislative diagnostics via the ISO 9141-2 K-line, the SCI transmit lines shall remain wire-ORed together for engine and transmission communications as specified in Configuration 'A'.
b. Configuration 'B'—Configuration 'B' shall be used in selective DaimlerChrysler Corporation (Chrysler Group) vehicles beginning in the 2002 model year, and shall eventually be used on all vehicle applications exclusively. Physical routing to ECUs shall be handled by providing a separate pair of SCI receive/transmit lines to each ECU. The engine ECU shall support an SCI receive/transmit pair terminated at pins 12 and 7, respectively. The transmission ECU shall support an SCI receive/transmit pair terminated at pins 9 and 15, respectively. In this regard, Configuration 'B' supports the independent interrogation and flash reprogramming of engine and transmission ECUs via SCI simultaneously. Additionally, SCI connections to pins 6 and 14 have been vacated to allow the migration to CAN to proceed without exception. This also permits the co-existence of both SCI and CAN vehicles using Configuration 'B', and supports full compliance to the SAE J1962 diagnostic connector requirements per the latest SAE publication.

6.3.2 DIAGNOSTIC CONNECTOR TERMINATIONS—The SAE J1962 connector terminal assignments are defined in Figure 3 for each DaimlerChrysler Corporation (Chrysler Group) vehicle configuration. SCI receive/transmit connections are depicted as gray-shaded assignments (viewed from the ECU perspective). Each configuration is shown compared against the SAE industry-standard reference.

Pin No.	SAE J1962 Terminal Assignment & Function	DaimlerChrysler Corporation Terminal Assignment & Function - Configuration 'A' -	DaimlerChrysler Corporation Terminal Assignment & Function - Configuration 'B' -
1	<Manufacturer Discretionary>	---	---
2	SAE J1850 (+)	SAE J1850 10.4Kbps VPW	SAE J1850 10.4Kbps VPW
3	<Manufacturer Discretionary>	---	---
4	Chassis Ground	Power Ground	Power Ground
5	Signal Ground	Signal Ground	Signal Ground
6	ISO 15765-4 CAN-C (+)	SCI Rx (Engine ECU) / Vpp Flash Strobe	ISO 15765-4 CAN Class-C (+) 500Kbps
7	ISO 9141-2 / ISO 14230-4 K-line	SCI Tx (Engine/Transmission ECUs)	SCI Tx (Engine ECU)
8	<Manufacturer Discretionary>	---	---
9	<Manufacturer Discretionary>	---	SCI Rx (Transmission ECU) / Vpp Flash Strobe
10	SAE J1850 (-)	---	---
11	<Manufacturer Discretionary>	---	---
12	<Manufacturer Discretionary>	---	SCI Rx (Engine ECU) / Vpp Flash Strobe
13	<Manufacturer Discretionary>	---	---
14	ISO 15765-4 CAN-C (-)	SCI Rx (Transmission ECU) / Vpp Flash Strobe	ISO 15765-4 CAN Class-C (-) 500Kbps
15	ISO 9141-2 / ISO 14230-4 L-line	---	SCI Tx (Transmission ECU)
16	Unswitched Battery Voltage	Battery Voltage	Battery Voltage

FIGURE 3—TERMINAL ASSIGNMENTS AND FUNCTION FOR SAE J1962 DIAGNOSTIC CONNECTOR CONFIGURATIONS

The SCI receive/transmit re-mapping from Configuration 'A' to Configuration 'B' is defined as follows:

a. Reroute pin 6 (Configuration 'A') to pin 12 (Configuration 'B') for **Engine SCI Rx**
b. Reroute pin 14 (Configuration 'A') to pin 9 (Configuration 'B') for **Transmission SCI Rx**
c. Vacate pin 6 and pin 14 for CAN-C (+) and CAN-C (-), respectively
d. Retain pin 7 (Configuration 'B') for **Engine SCI Tx** only
e. Separate and reroute pin 7 (Configuration 'A') to pin 15 (Configuration 'B') for **Transmission SCI Tx**

The routing for each diagnostic connector configuration is depicted graphically in Figures 4 and 5.

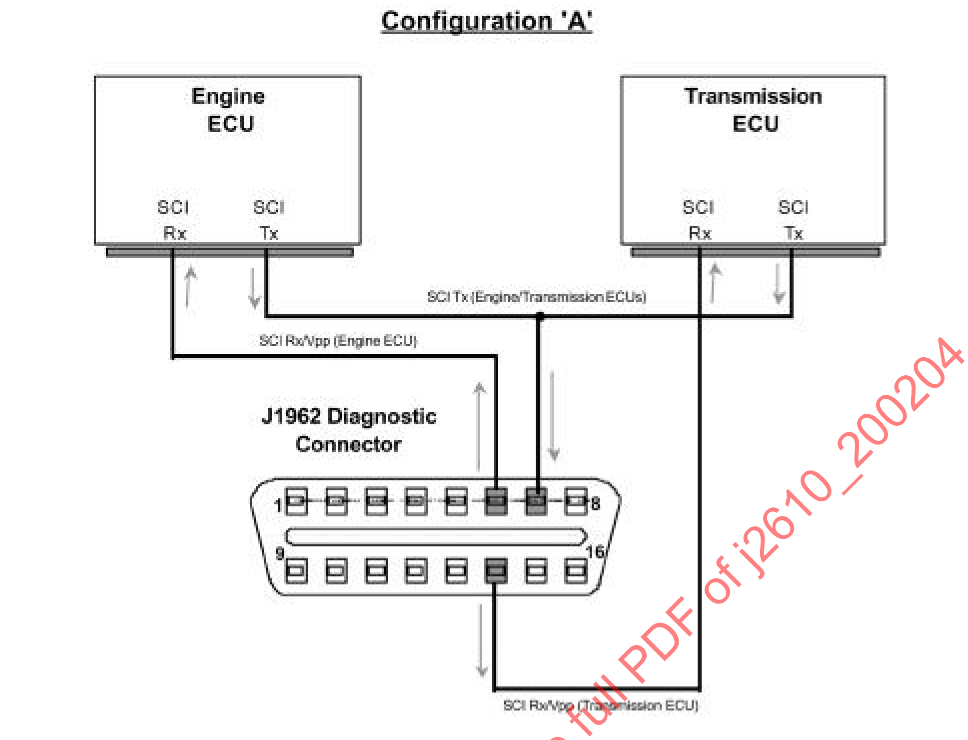


FIGURE 4—OLD CONFIGURATION 'A' DEPICTED WITH SINGLE SCI TX LINE SHARED PER PAIR OF EMISSION ECUS

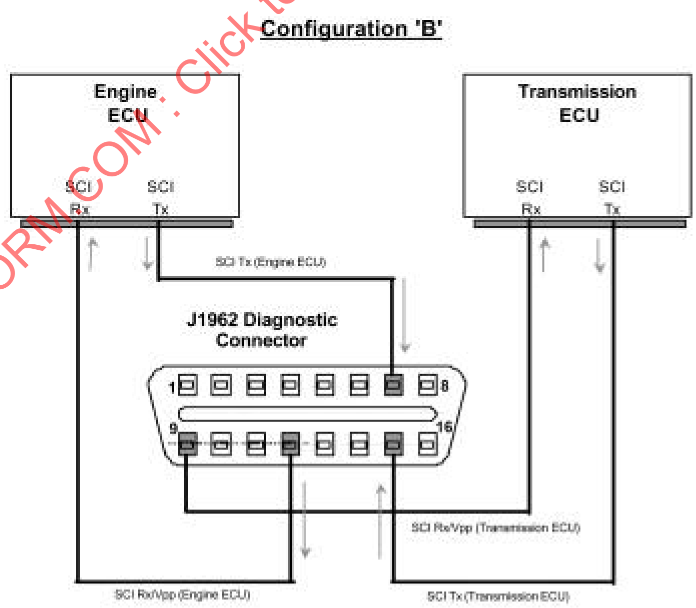


FIGURE 5—NEW CONFIGURATION 'B' DEPICTED WITH INDEPENDENT SCI RX/TX LINES PER EACH EMISSION ECU

6.3.3 DIAGNOSTIC CONNECTOR MULTIPLEXING—Multiplexing of the SAE J1962 diagnostic connector terminals shall be required by the diagnostic tester to support the two vehicle configurations as follows:

a. Configuration 'A'—For Configuration 'A', connector pins 6 and 14 shall be multiplexed between SCI functionality and ISO 15765-4 CAN functionality under software control. SCI connections to pins 6 and 14 shall not electrically interfere with ISO 15765-4 CAN operation. Both pins must transition simultaneously between data link types when requested. When the SCI mode is selected by the tester, both pins 6 and 14 must support SCI transmit with Vpp flash strobe function under software control. The default settings for the SCI channel function are 7812.5 bps with flash strobe 'OFF'. Connector pin 7 shall function as either an SCI receiver, or an ISO 9141-2 bi-directional transceiver under software control. SCI connections to pin 7 shall not electrically interfere with ISO 9141-2 operations, and shall be able to be pulled to either vehicle battery or 5 V DC under programmable control.
b. Configuration 'B'—For Configuration 'B', connector pins 9 and 12 shall be configured for SCI functionality. When the SCI mode is selected by the tester, both pins 9 and 12 must support SCI transmit with Vpp flash strobe function under software control. Either connector pin transitions independently with SCI mode enabled. The default settings for the SCI channel function are 7812.5bps with flash strobe 'OFF'. Connector pins 7 and 15 shall function as either an SCI receiver, or an ISO 9141-2 transceiver under software control. SCI connections to pins 7 or 15 shall not electrically interfere with ISO 9141-2 operations, and shall be able to be pulled to either vehicle battery or 5 V DC under programmable control.

For additional details regarding the multiplexing of the Vpp flash strobe requirements during a flash reprogramming session, please refer to Section 9 “Reprogramming Requirements”.

6.4 Media Characteristics—The SCI physical media shall be defined as a dual-wire, unshielded, twisted-pair interface.

6.4.1 IMPEDANCE—Impedance characteristics shall be dictated by the interface circuitry as specified in the ECU receiver/transmitter reference circuits in 6.5.

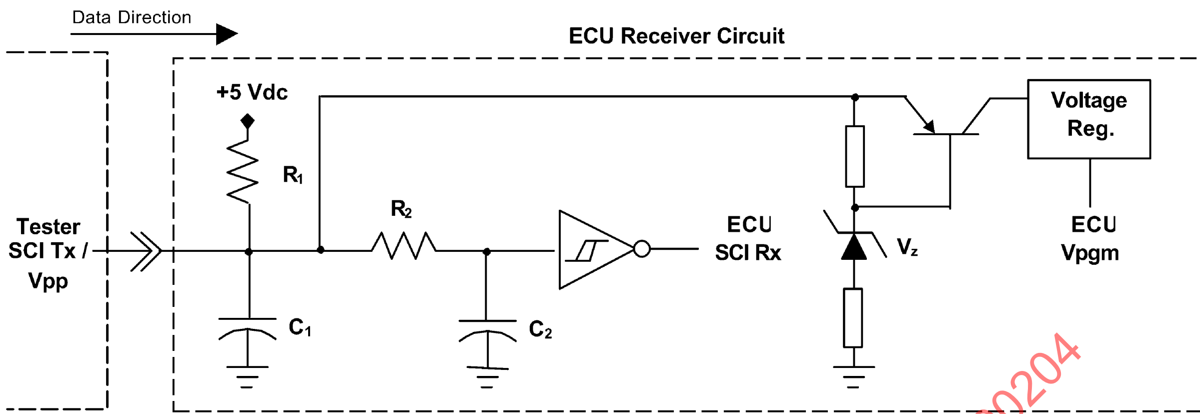
6.4.2 INTERFACE CABLE CONSIDERATIONS—The diagnostic tester interface cable shall not exceed a maximum of 5m in length.

The interface cable may be constructed using one of the following methods:

a. By using two jumper connectors in the interface cable, backward compatibility between Configuration 'A' and Configuration 'B' can be supported with minimal tester software overhead. This is accomplished by shorting connector pins 6 and 12 together for engine ECU and connector pins 9 and 14 together for transmission ECU, and promotes a single interface cable usage for old vs. new connector configurations. The same goal can be accomplished using a cable adapter with the jumpers integrated into the adapter. However, the interface cable and/or adapter connector will constitute special requirements for DaimlerChrysler Corporation (Chrysler Group) vehicles, and as such, may be a less desirable solution. Additionally, this set-up cannot be used for CAN vehicles.
b. By not using any jumper connectors in the interface cable, tester detection of connector configuration can be supported through software polling techniques. Several methods for ECU response detection via connector pins 7 and 15 are possible. This approach allows a standard interface cable to be used for all vehicles.

6.5 ECU Receiver/Transmitter Reference Circuits—The following figures depict functionally equivalent SCI receive and transmit circuits for an ECU.

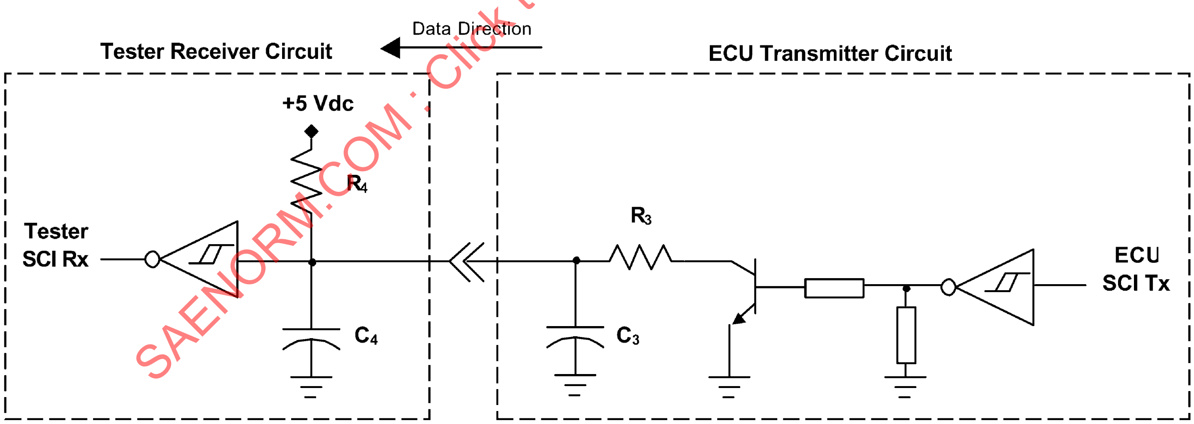
6.5.1 SCI RX LINE—The ECU receive circuit shall contain provisions to support SCI communications as well as Vpp flash strobe requirements multiplexed on the same line by the diagnostic tester. A typical ECU receive circuit is shown illustrated in Figure 6.



Component Description	Min. Value	Nominal Value	Max. Value	Units
Resistor, R_1		10,000		ohms
Resistor, R_2		10,000		ohms
Capacitor, C_1		1,000		picofarads
Capacitor, C_2		33	100	picofarads

FIGURE 6—REPRESENTATIVE ECU RECEIVER CIRCUIT WITH TYPICAL COMPONENT VALUES

6.5.2 SCI TX LINE—The ECU transmit circuit shall contain an open-collector style circuit to drive a diagnostic tester receive circuit such as the one illustrated in Figure 7. The tester must provide adequate pull-up resistance as shown.



Component Description	Min. Value	Nominal Value	Max. Value	Units
Resistor, R_3		82		ohms
Resistor, R_4		1,000	2,000	ohms
Capacitor, C_3		470	1,880	picofarads
Capacitor, C_4		470	1,000	picofarads

FIGURE 7—REPRESENTATIVE ECU TRANSMITTER CIRCUIT WITH TYPICAL COMPONENT VALUES

7. Data Link Layer—The SCI Data Link Layer is responsible for transferring data between the SCI Physical Layer and the Message Application Layer. The SCI Data Link Layer defines the data frame elements, format, length, inter-frame timing, and error handling conditions.

7.1 Data Frame Definition—Asynchronous data transmission implies that each data frame shall be transmitted individually. This section defines the grouping of data bits that comprise an SCI data frame. A data frame is defined as one complete transmission of information delineated by the start of frame (start bit) and end of frame (stop bit) identifiers. These start and stop bits define the boundaries of a single data frame for the receiver to properly interpret.

7.1.1 LENGTH AND FORMAT—The data frame size shall be defined as ten (10) bits in length (i.e., one start bit, eight data bits, and one stop bit with no parity). The format of the data frame shall be defined as follows:

a. One (1) Start Bit:One start bit with logic “0” (low) for one bit time duration. The start bit is defined as the first binary element transmitted in the asynchronous transmission of a data frame. It is used to uniquely identify the beginning of a data frame transmission to synchronize the receiver to an active session.
b. Eight (8) Data Bits:Eight data bits transmitted from Least Significant Bit (LSB) to Most Significant Bit (MSB). The data bits comprise the byte or character value contained in the data frame bounded by the start and stop bits.
c. One (1) Stop Bit:One stop bit with logic “1” (high) for one bit time duration. The stop bit is defined as the last binary element transmitted in the asynchronous transmission of a data frame. It is used to uniquely identify the end of a data frame transmission to return the receiver to an idle condition.
d. No Parity Bit:No parity bit in the default data frame. Therefore, no parity checking is available in the transmitted data frame.

Figure 8 illustrates this pattern:

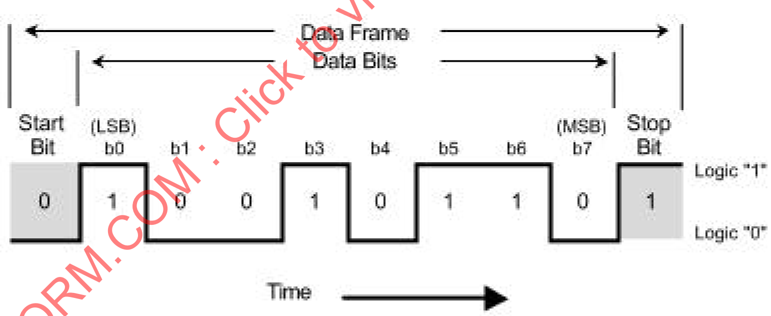


FIGURE 8—THIS EXAMPLE DEPICTS THE DATA FRAME TRANSMISSION OF CHARACTER $69

7.2 Inter-Frame Timing—An SCI receiver shall be capable of receiving 255 consecutive data frames with zero (0) inter-frame delay. Inter-frame delay is defined as the time between the end of one data frame and the start of the next data frame. Zero inter-frame delay implies that data is being transferred as fast as the data rate allows. If a diagnostic tester cannot receive a stream of 255 consecutive data frames with zero (0) inter-frame delay, then a slower data rate should be negotiated between the diagnostic tester and the ECU.

Although the SCI communication link is a full-duplex serial interface, in some communication sessions a half-duplex mode is required. Half-duplex mode implies that the SCI communication system is capable of bi-directional communications but only in one direction at a time. In the half-duplex mode, every data frame sent by the diagnostic tester is “echoed” by the ECU. The tester shall not send the next data frame until receiving the expected echo from the ECU. Upon receiving the echo, the tester shall assume the ECU is ready for the next sequential data frame. Although the ECU shall echo the appropriate data frame as intended, this shall not imply that the command sequence has been fully serviced by the ECU. An additional delay time may be required by the ECU for processing the request before a command sequence has been completed. This half-duplex mode allows the timing sequence to be completely managed by the diagnostic tester. This strategy prevents data frame overruns from occurring, but also effectively limits the data throughput. That is, the diagnostic tester shall wait for the echoed response character before sending the next request. This is illustrated in Figure 9:

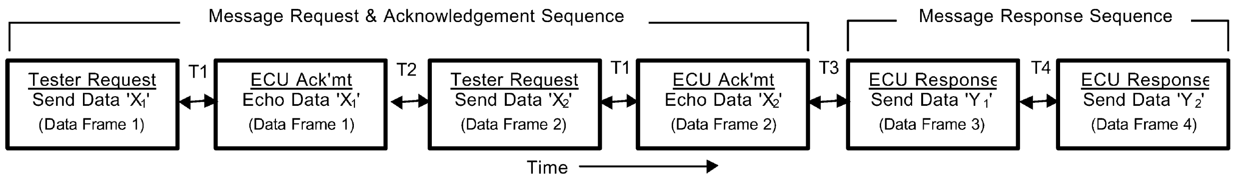


FIGURE 9—TWO-FRAME MESSAGE REQUEST/ACKNOWLEDGEMENT SEQUENCE WITH A TWO-FRAME MESSAGE RESPONSE DURING A DIAGNOSTIC SESSION

Additionally, multiple-frame command sequences may be sent to an ECU without echoing each character. In this case, a response shall occur within a given timeframe. Otherwise, a communication timeout event shall be declared, and the ECU shall disregard the entire command sequence. This is illustrated in Figure 10:

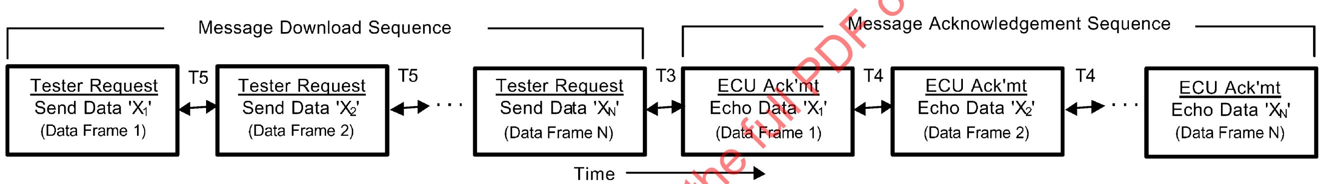


FIGURE 10—MULTIPLE-FRAME MESSAGE DOWNLOAD SEQUENCE WITH A MULTIPLE-FRAME ACKNOWLEDGEMENT DURING A REPROGRAMMING SESSION

The following timing parameters in Figure 11 shall apply to all communication modes:

Delay Period	Description of Delay Time Period (T_X)	Low-Speed Mode		High-Speed Mode	
		Min. Delay (milliseconds)	Max. Delay (milliseconds)	Min. Delay (milliseconds)	Max. Delay (milliseconds)
T1	**ECU Inter-Frame 'Response' Delay** Defines the response delay from the ECU after receiving a valid data transmission from the tester	0	20	0	1
T2	**Tester Inter-Frame 'Request' Delay** Defines the request delay from the tester after receiving a valid data acknowledgement from the ECU	0	100	0	1
T3	**ECU Inter-Message 'Processing' Delay for Initial Data Transmission** Defines the response delay from the ECU after processing a valid request message from the tester	0	50	0	5
T4	**ECU Inter-Frame 'Response' Delay for Subsequent Data Transmission(s)** Defines the response delay from the ECU after transmitting the first data frame in a multiple frame transmission	0	20	0	0
T5	**Tester Inter-Frame 'Request' Delay for Subsequent Data Transmission(s)** Defines the request delay from the tester after transmitting the first data frame in a multiple frame transmission	0	100	0	0

FIGURE 11—TIMING DELAY PARAMETERS LISTED AS A FUNCTION OF COMMUNICATION MODE

7.3 Error Handling

7.3.1 Error Detection—There are several distinct types of detectable SCI communication errors. A diagnostic tester and ECU shall monitor for framing, overrun, and noise communication errors. The SCI “frame level” communication errors are defined as follows:

a. Framing Error:A framing error is set when the SCI receiver detects a logic “0” where a stop bit (logic “1”) should occur. A framing error results when the frame boundaries in the received bit stream are not synchronized with the receiver bit counter. This is usually caused by mismatched data rates between receiver and transmitter. Note that a BRK condition may set a framing error.
b. Overrun Error:An overrun error is set when the SCI receiver has not transferred data from its internal receive buffer before new data arrives. Data transfer between ECU and tester is inhibited until this receive buffer can be cleared. Previous data in the receive buffer is still valid, but all data received after the overrun condition was declared is discarded.
The SCI “bt level” communication errors are defined as follows:
c. Noise Error:A noise error is set when the SCI receiver has detected noise on a valid start bit, stop bit, or data bit. A noise error results when the sampled bit in the received bit stream assumes different states or an indeterministic state based on a sampling frequency of the logic level. The sampling frequency is determined by the SCI receiver.

7.3.2 Error Correction/Recovery—If an SCI communication error is detected, the SCI receiver shall reject the request, discard any message contents, and refrain from sending any response character. Possible recovery strategies include:

a. Wait for a communication session timeout
b. Request a retransmission of the previous data frame
c. Request a change in communication parameters (e.g., reduction in data rate)

In the high-speed mode, the ECU shall monitor for framing and overrun communication errors. If a framing or overrun error is detected, the ECU shall record the error event to accumulate the number of occurrences. When a maximum number of ten (10) errors have been detected, the ECU shall reset the data rate to the default low-speed mode and clear the error accumulation counter to zero. The noise error is not tracked for frequency of occurrence in the high-speed mode.

In the low-speed mode, the ECU shall monitor for framing, overrun, and noise communication errors. If no communication errors are detected during a 100 milliseconds sampling period, re-establishment of the high-speed mode shall be allowed.

8. Message Application Layer—The Message Application Layer transforms SCI data frames received from the Data Link Layer into application-specific messages. Additionally, the Message Application Layer maps application-specific messages back into data frames to be transferred by the Data Link Layer. The Message Application Layer can support many industry-standard or proprietary application-specific protocols. Application-specific protocols that utilize the SCI communication link include the SCI Diagnostic Protocol for PCM Applications, and the SAE J2190 Diagnostic Protocol for PCM Applications as applied to the diagnosis of DaimlerChrysler Corporation (Chrysler Group) vehicles.

8.1 Message Frame Structure—An SCI message frame shall be defined as an ordered collection of SCI data frames. Since SCI is a dedicated point-to-point communication link, no message header is required for specifying the addressing format or error checking. This permits full usage of the communication bandwidth. The message frame shall have the following free-form structure as shown in Figure 12:

Data bytes 1 to N shall comprise the message data area. The message data area may or may not contain error checking. The message length may vary depending on the application-specific protocol requirements.

Byte No.	Data Value	Description
1	Data 1	Start of message data
2	Data 2	
.		
.		
.		
N	Data N	End of message data

FIGURE 12—ARBITRARY MESSAGE FRAME STRUCTURE FOR SUPPORT OF MULTIPLE PROTOCOLS

9. Reprogramming Requirements—The SCI communication link is utilized in the flash reprogramming of emission-related powertrain devices. Additional requirements apply when reprogramming emission-related ECUs via the SCI communication link. To that end, this section defines the application of protective security mechanisms, hardware interlock requirements, and flash strobe requirements as applied to the reprogramming of emission-related ECUs.

9.1 Security—The diagnostic tester shall secure the flash reprogramming process by retaining all required reprogramming information off-board the vehicle (i.e., resident in the tester). The tester shall provide the ECU with the proper software routines, algorithms, and loaders containing the necessary instructions for download, checksum, erase, and program. These routines are only temporarily downloaded into volatile RAM on-board the ECU for the current diagnostic session. These functions shall only be allowed following the initialization of secured access to ECU boot-loader functions.

9.2 Block Transfer—Data targeted for the reprogramming of a memory device shall be segmented into data blocks for download into the ECU. The data block size, format, and integrity verification process shall be as defined below.

9.2.1 LENGTH AND FORMAT—The data block shall not exceed 4K bytes in length. The format of each block shall minimally contain a header composed of the target memory address (defined as the absolute memory address location) followed by a block length identifier.

9.2.2 VERIFICATION—Data block verification can be performed using various procedures and methods. Most commonly, a checksum is performed and verified from the data stream echoed by the ECU to the diagnostic tester. Data is downloaded into the ECU RAM by the tester, flashed into PROM, read from PROM, and compared to RAM on a per byte basis. It is then echoed back to the diagnostic tester. A final checksum of the entire program code shall be performed following completion of the flash process.

9.3 Hardware Interlock—The hardware interlock shall be required to externally trigger the ECU into entering the special boot-loader mode following hardware reset. This interlock enables a “flash-ready” mode not achievable through normal software control. It is used to enhance the secured process through the implementation of an additional protective safeguard. Since the vehicle is unable to generate the Vboot signal level required for initiating boot-loader mode, no boot-block functions can be inadvertently accessed. The hardware interlock is stimulated by the flash strobe voltage multiplexed on the ECU SCI receive line. Once the hardware interlock has been initiated, a hardware reset is required to permit the ECU to enter a “load-and-go” boot-loader mode to allow off-board routines to be downloaded and executed. The flash strobe signal is used as a comparative voltage on the Vboot control input for the ECU bootstrap software to detect. The hardware reset is accomplished through cycling of the ignition key.