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(R) SERIAL DATA COMMUNICATIONS BETWEEN MICROCOMPUTER SYSTEMS IN HEAVY DUTY VEHICLE APPLICATIONS

FOREWORD

This SAE/TMC Joint Recommended Practice has been developed by the Truck and Bus Electronic Interface Subcommittee of the Truck and Bus Electrical Committee and by the S.1 Study Group of the Maintenance Council. The objectives of the subcommittee are to develop information reports, recommended practices, and standards concerned with the interface requirements and connecting devices required in the transmission of electronic signals and information among truck and bus components.

Objectives: Some of the goals of the subcommittee in developing this document were to:

a. Minimize hardware cost and overhead;

b. Provide flexibility for expansion and technology advancements with minimum hardware and software impact on in-place assemblies;

c. Utilize widely accepted electronics industry standard hardware and protocol to give designers flexibility in parts selection;

d. Provide a high degree of electromagnetic compatibility;

e. Provide original equipment manufacturers, suppliers, and aftermarket suppliers the flexibility to customize for product individuality and for proprietary considerations.

1. SCOPE:

This document defines a recommended practice for implementing a bidirectional, serial communication link among modules containing microcomputers. This document defines those parameters of the serial link that relate primarily to hardware and basic software compatibility such as interface requirements, system protocol, and message format. The actual data to be transmitted by particular modules, which is an important aspect of communications compatibility, is not specified in this document. These and other details of communication link implementation and use should be specified in the separate application documents referenced in Section 2.

1.1 Purpose:

The purpose of this document is to define a general-purpose serial data communication link that may be utilized in heavy duty vehicle applications. It is intended to serve as a guide toward standard practice to promote serial communication compatibility among microcomputer-based modules. The primary use of the general-purpose communications link is expected to be the sharing of data among stand-alone modules to cost effectively enhance their operation. Communication links used to implement functions that require a dedicated communication link between specific modules may deviate from this document.

2. REFERENCES:

It is recommended that a separate applications document be published by the manufacturer for each device using the serial link. These documents should define the data format, message I.D.'s, message priorities, error detection (and correction), maximum message length, percent bus utilization, and methods of physically adding/removing units to/from the line for the particular application.

2.1 Applicable Documents:

SAE J1455 Joint SAE/TMC Recommended Environmental Practices for Electronic Equipment Design (Heavy Duty Trucks)

SAE J1587 Joint SAE/TMC Recommended Practice for Electronic Data Interchange Between Microcomputer Systems in Heavy Duty Vehicle Applications

SAE ~~J1992~~ 1922 Powertrain Control Interface for Electronic Controls Used in Medium and Heavy Duty Diesel on Highway Vehicle Applications

Electronics Industries Association Standard RS-485 (EIA RS-485) "Standard for Electrical Characteristics of Generators and Receivers for Use in Balanced Digital Multipoint Systems," April 1983

2.2 Definitions:

2.2.1 ACCESS TIME: Two bit times multiplied by the message priority (which ranges from 1 to 8) added to the idle line time.

2.2.2 BAUD: The maximum number of analog signal transitions per second that can occur on a channel. In this coding system, this is the reciprocal of the bit time.

2.2.3 BIT TIME: Duration or period of one unit of information.

2.2.4 CHARACTER TIME: The duration of one character. The character must start with a low logic bit, then 8 bits of data (least significant bit first) followed by a high logic level stop bit.

2.2.5 CONTENTION: A state of the bus in which two or more transmitters are turned on simultaneously to conflicting logic states.

2.2.6 DIFFERENTIAL SIGNAL: A two-wire process in which both lines are switches as opposed to a single-ended signal wherein one line is grounded and the signal line is switched between logic states.

2.2.7 IDLE STATE: The state that produces a high logic level on the input of the bus receiver when all transmitters on the network are turned off.

2.2.8 IDLE LINE: The condition that exists when the bus has remained in a continuous high logic state for at least 10 bit times after the end of the last stop bit.

NOTE: The idle line serves as the delimiter between messages on the bus. A receiver that cannot distinguish between a stop bit and any other high logic state may become synchronized with the bus by noting the receipt of 12 consecutive high logic bits. In the absence of errors, the first low logic bit (0) following 12 consecutive high logic bits (1) is the start bit of a message identification character (MID) (that is, the first character of a message).

2.2.9 MESSAGE PRIORITY: A measure of message criticality assigned on a scale of 1 to 8 by the appropriate applications document. The most critical message has a priority of one.

2.2.10 NODE: A receiver or transceiver circuit connected to the bus.

2.2.11 START BIT: Initial element of a character defined as a low logic level of 1 bit time duration as viewed at the output of the bus receiver.

2.2.12 STOP BIT: Final element of a character defined as a high logic level of 1 bit time duration as viewed at the output of the bus receiver.

3. ELECTRICAL PARAMETERS:

The electrical parameters of this serial data link are a modification of the EIA RS-485 standard. In some areas this document conflicts with RS-485. This document shall serve as the guiding document in such cases. Appendix A details a serial data bus standard node which defines the interface circuit parameters. Operation of this standard node is detailed in this section.

3.1 Logic State:

Positive true logic will be used when referring to the states of transmitted inputs and received outputs. Referring to Appendix A, the input of the transmitter (marked as point Tx) and the output of the receiver (marked as Rx) will be in logic 1 state when driven or passively pulled to +V, and will be at a logic 0 state when driven to ground.

3.2 Bus State:

The bus is in a logic 1 (high) state whenever Point A is at least 0.2 V more positive than Point B. The bus is in a logic 0 (low) state whenever Point A is at least 0.2 V more negative than Point B (Points A and B, refer to Figure A1). The bus state is indeterminate when the differential voltage is less than 0.2 V.

3.2.1 Logic High State: The bus will be in a logic 1 (high) state when all connected transmitters are idle or sending logic 1. An idle state is produced when all transmitters on the network are turned off. All nodes shall include means to pull the bus to a logic 1 (high) when all transmitters are off (see Appendix A).

3.2.2 Logic Low State: The bus will be in a logic 0 (low) state when one or more transmitters are sending logic 0, which guarantees that logic 0 (low) dominates when the bus is in contention.

3.3 Network Capacity:

The bus will support a minimum of 20 standard nodes where each node is comprised of the circuit defined in Appendix A. Deviations from this circuit must be carefully analyzed to determine impact on bus loading and noise margins over the common mode range.

3.4 Bus Termination:

Bus termination resistors as referenced in RS-485 are not required and shall not be used.

3.5 Ground:

All assemblies using the link must have common ground reference.

3.6 Wire:

A minimum of 18 gauge twisted pair wire, with a minimum of one twist (360 degrees) per inch (2.54 cm), is required. The twists shall be distributed evenly over the length of the wire.

3.7 Length:

This recommended practice is intended for, but not limited to, applications with a maximum length of 130 ft (40 m).

4. NETWORK PARAMETERS:

4.1 Network Topology:

The network interconnect shall use a common or global bus.

4.2 Network Access:

The method of access to the network is random.

4.2.1 Bus Access: A transmitter shall begin transmitting a message only after an idle state has continuously existed on the bus for at least a bus access time. The transmitter must verify that the idle state continues to exist immediately prior to initiating a transmission (that is, within one-half bit time).

4.2.1.1 Bus Access Time: Bus access time is a time duration equal to the minimum time of an idle line plus the product of 2 bit times and the message priority. This relationship can be expressed as follows:

$$T_a = T_i + \left[2 * T_b \right] * P \qquad \text{(Eq.1)}$$

where:

T_a = Bus access time
T_b = Bit time, or period of one unit of information
P = Message priority
T_i = Minimum time duration of an idle line

NOTE: The minimum time duration of an idle line is defined in 2.2.9. However, a transmitter that cannot distinguish between a stop bit and any other high logic state may not assume that Ti has elapsed until it has received 19 consecutive high logic bits.

4.2.1.2 Message Priority Assignment: All messages will be assigned a priority from 1 to 8 as indicated in Table 1:

TABLE 1

Priority	Message Assignment
1 and 2	Reserved for messages that require immediate access to the bus
3 and 4	Reserved for messages that require prompt access to the bus in order to prevent severe mechanical damage
5 and 6	Reserved for messages that directly affect the economical or efficient operation of the vehicle
7 and 8	All other messages not fitting into the previous priority categories should be assigned a priority 7 or 8

4.2.1.2 (Continued):

The applications document shall define the priority associated with each message. In the event that more than one priority could be assigned to a particular message, the application document shall define each priority and the circumstances in which the priority is assigned.

4.2.2 Bus Contention: All transmitters shall monitor the message identification portion of their message to determine if another transmitter has attempted to gain access to the bus at the same time. If a transmitter detects a collision, the transmitter shall relinquish control of the bus after completing the transmission of the current character or sooner if possible. After relinquishing control, it is recommended that the transmitter become a receiver, using the received MID as the beginning of the incoming message. The transmitter may attempt to regain access to the bus after a bus access time has elapsed. An example bus reaccess procedure is shown in Appendix B.

5. PROTOCOL:

5.1 Bit Time:

A bit time shall be 104.17 μs ± 0.5% (±500 ns). This is equivalent to a baud rate of 9600 bits per second.

5.2 Character Format:

A character shall consist of 10 bit times. The first bit shall always be a low logic level and is called the start bit. The last (tenth) bit shall always be a high logic level and is called the stop bit.

5.2 (Continued):

This convention is consistent with standard UART operation. The remaining eight center bits are data bits that are transmitted least significant bit (LSB) first.

5.3 Message Format:

5.3.1 Message Content: A message appearing on the communication bus shall consist of the following:

a. Message Identification Character (MID);
b. Data Characters;
c. Checksum.

As indicated in 4.2.1, a message shall always be preceded by an idle state of duration equal to or greater than the appropriate bus access time. The length of time between characters within a message shall not exceed 2 bit times.

5.3.2 Message Identification Character (MID): The first character of every message shall be a MID. The permitted range of MIDs shall include the numbers 0 to 255. The MIDs 0 to 68 shall be assigned to transmitter categories as identified in Table 2. These assignments have been made to accommodate existing systems, or systems that may presently be under development, and to avoid conflicts, which otherwise might arise if indiscriminate use of MIDs were permitted.

MIDs 69 to 86 have been set aside for use by the SAE J1922.

MIDs 87 to 110 shall be allocated as reserved MIDs for transmitter categories beyond those that are identified in Table 2. These MIDs shall be individually assigned by the SAE Electronics Interface Subcommittee of the SAE Truck and Bus Electrical Committee on petition by a manufacturer at the time a new transmitter category is identified, or when additional MIDs are required within a previously identified category. The content and format of the messages using the assigned MIDs (0 to 110) is the responsibility of the transmitter. Content of format of the data within these messages is not defined in this document but should be identified in an appropriate applications document as described in Section 2.

MID 111 shall be used exclusively for factory test of electronic modules. Since it is possible that during factory test the normal control software is bypassed, giving the tester direct control of module I/o, several precautions should be observed:

a. Entry into factory test should be granted by the module control software only after ensuring that it is safe to do so.

b. This MID should not be transmitted by any on-board module.

MIDs 112 to 127 are not assigned to any category and are not reserved for future assignment. These MIDs are available to any manufacturer or user for any message identification purpose outside the scope of this document.

TABLE 2 - Message Identification Character Allocation

Mid Range	Transmitter Category
00-07	ENGINE
08-09	BRAKES, TRACTOR
10-11	BRAKES, TRAILER
12-13	TIRES, TRACTOR
14-15	TIRES, TRAILER
16-17	SUSPENSION, TRACTOR
18-19	SUSPENSION, TRAILER
20-27	TRANSMISSION
28-29	ELECTRICAL CHARGING SYSTEM
30-32	ELECTRICAL
33-35	CARGO REFRIGERATION/HEATING
36-40	INSTRUMENT CLUSTER
41-45	DRIVER INFORMATION CENTER
46-47	CAB CLIMATE CONTROL
48-55	DIAGNOSTIC SYSTEMS
56-61	TRIP RECORDER
62-63	TURBOCHARGER
64-68	OFF-BOARD DIAGNOSTICS
69-86	SET ASIDE FOR SAE J1922
87-110	RESERVED - TO BE ASSIGNED BY ELECTRONIC INTERFACE SUB-COMMITTEE (see 5.3.2, Section 3).
111	RESERVED - FACTORY ELECTRONIC MODULE TESTER (OFF VEHICLE)
112-127	UNASSIGNED - AVAILABLE FOR USE
128-255	TO BE ASSIGNED BY DATA FORMAT SUBCOMMITTEE (see 5.3.2.)

5.3.2 (Continued):

MIDs in the 0 to 68 and 87 to 127 ranges shall be defined in the manufacturer's applications document. It shall be the responsibility of the systems integrator or user to ensure that a particular MID is not used by more than one device on the same vehicle.

MIDs in the range of 128 to 255 shall be reserved for applications using formatted data as set forth in a document issued by the SAE Truck and Bus Electrical Committee Data Format Subcommittee. These MIDs shall only be used when the data format set forth within that document is strictly followed. See SAE J1587.

5.3.3 Data Characters: Data characters shall be characters that convey the intelligence of the message and shall conform to the character format as defined in 5.2. The 8 bit data character may be given any value from 0 to 255. The data characters shall be defined in an appropriate applications document at the option of the supplier. The application document shall define parameters, parameter order, scaling and error detection/correction coding if applicable.

5.3.4 Checksum: The last character of each message shall be the two's complement of the sum of the MID and the data characters. Simple message error detection may be implemented by adding the checksum to the sum of all previous message characters (including the MID). The 8 bit sum will be zero, neglecting the CARRY, for a correctly received message.

5.3.5 Message Length: Total message length, including MID and checksum, shall not exceed 21 characters. Exceptions to this length limitation may be made when the engine is not running and the vehicle is not moving. Messages longer than 21 characters may also be broken up into several separate messages of 21 or fewer characters and may then be transmitted while the engine is running and/or the vehicle is moving by conforming to the 21 character message length limitation of SAE J1708.

APPENDIX A

Serial Data Bus Standard Node
(Unipolar Drive With Passive Termination in Each Module)

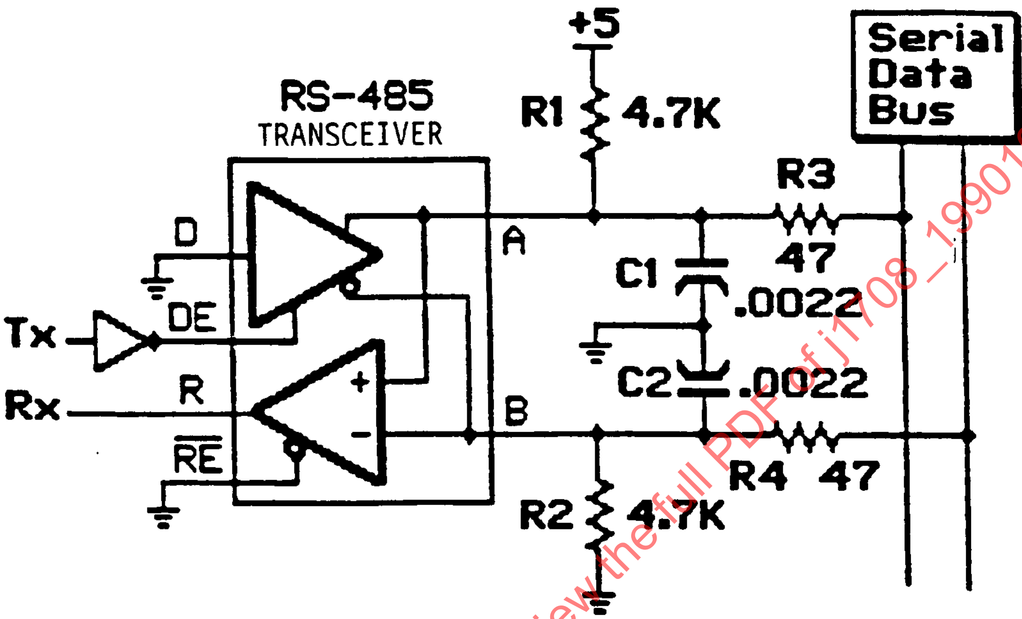

FIGURE A1 - Serial Data Bus Standard Node Diagram

A.1 This circuit utilizes standard RS-485 transceivers (less than or equal to one RS-485 unit load) connected to drive the differential data bus to the logic zero state only (unipolar drive). In the above circuit, a standard RS-485 receiver may be used in place of a transceiver in applications where data need not be placed on the bus (that is, receive only).

A.2 The logic one state (also idle state) is controlled by pull-up resistor R1 and pull-down resistor R2.

A.3 The transceiver output impedance, C1 and C2, form the transmit filter for transient and EMI suppression (approximately 6 MHz low pass).

A.4 R3, C1, R4, and C2 form the receive filter for EMI suppression (approximately 1.6 MHz low pass). These parts also form a pseudo line termination at high frequencies.

A.5 The active (high-to-low) transition delay is approximately 0.6 µs at the receiver with two nodes on the bus and 2.3 µs with 20 nodes on the bus.

A.6 The passive (low-to-high) transition delay at the receiver remains at 10 µs with any number of loads on the bus (up to 20).

A.7 The values shown were chosen for use with commercially available RS-485 drivers to provide maximum fan-out, EMI suppression, and bus termination. Remaining nodes may be in either the powered or unpowered state.

A.8 This method of unipolar drive prevents unresolved contention (logic zero always wins).

A.9 The resistors shown should be 5% parts to assure sufficient noise margin under worst case conditions. R3, R4, C1, and C2 should be balanced within 10% on each side of the data bus to minimize common mode electromagnetic radiation.

APPENDIX B

Example Bus Reaccess Procedure

B.1 A method for reaccessing the bus can be described by the following example:

B.1.1 Sequence of Events:

a. First crash occurs for the current attempt to access the bus.

b. Each device wishing to access the bus then waits their predefined bus access time (as described in 4.2.2).

c. Second crash occurs for the same attempt to access the bus.

d. Any device that has experienced two consecutive crashes in its attempt to transmit the same message shall follow the bus access procedure defined in 4.2.1 but with the bus access time calculated as follows:

$$T_a = T_i + 2 + P_2 \times T_b \qquad \text{(Eq.B1)}$$

where:

T_i and T_b are defined as in 4.2.1.1.

P_2 = A three bit psuedo random number such as the three least significant bits of the stack pointer.

For example, if 18 is the location of stack pointer register, the contents of this register is the stack pointer. This value will be ANDED with 0007, which results in a number from 0 to 7. P_2 would, therefore, be a value from 0 to 7.

e. If any more consecutive crashes occur, the procedure described in d is repeated.

B.2 This example addresses the recognized possibility that two or more devices could continue to crash if their priorities were the same. The above method would greatly reduce the possibility of a third crash with the same device or devices.

The (R) symbol 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.