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Serial Data Communications Between Microcomputer Systems in Heavy-Duty Vehicle Applications

RATIONALE

This document has been determined to contain basic and stable technology which is not dynamic in nature.

STABILIZED NOTICE

This document has been declared "Stabilized" by the SAE Truck and Bus Low Speed Communication Network Committee and will no longer be subjected to periodic reviews for currency. Users are responsible for verifying references and continued suitability of technical requirements. Newer technology may exist.

FOREWORD

The SAE group responsible for the content of this recommended practice was revised to the SAE Low Speed Communications Network Subcommittee sponsored by the SAE Truck and Bus Electrical and Electronics Committee. This Document was revised to comply with the new SAE Technical Standards Board format.

Earlier versions of this document stated: 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.

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1. SCOPE

This SAE Recommended Practice 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

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

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.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

SAE J1455 Recommended Environmental Practices for Electronic Equipment Design in Heavy-Duty Vehicle Applications

SAE J1587 Electronic Data Interchange Between Microcomputer Systems in Heavy-Duty Vehicle Applications

SAE J1922 Powertrain Control Interface for Electronic Controls Used in Medium- and Heavy-Duty Diesel On-Highway Vehicle Applications

SAE J2497 Power Line Carrier Communications for Commercial Vehicles

2.1.2 EIA Publication

Available from Electronic Industries Alliance, 2500 Wilson Boulevard, Arlington, VA 22201-3834, Tel: 703-907-7500, www.eia.org.

EIA RS-485 Standard for Electrical Characteristics of Generators and Receivers for Use in Balanced Digital Multipoint Systems, April 1983

3. DEFINITIONS

3.1 BUS ACCESS TIME

A time duration equal to the minimum time of an Idle Line plus the product of 2 bit times and the message priority (which ranges from 1 to 8). An example is shown in 5.2.2.3.

3.2 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.

3.3 BIT TIME

Duration or period of one unit of information.

3.4 CHARACTER

A character shall consist of 10 bit times. 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.

3.5 CHARACTER TIME

The duration of one character which is equal to 10 bit times.

3.6 CONTENTION

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

3.7 DIFFERENTIAL SIGNAL

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

3.8 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.

3.9 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. The minimum time duration of an idle line is 10 bit times. An example is shown in 5.2.1.

NOTE: The idle line serves as the delimiter between messages on the bus.

3.10 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.

3.11 NODE

A receiver or transceiver circuit connected to the bus.

3.12 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.

3.13 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.

4. 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 EIA 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.

4.1 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.

4.2 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.

4.2.1 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).

4.2.2 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.

4.3 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.

4.4 Bus Termination

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

4.5 Ground

All assemblies using the link must have common ground reference.

4.6 Wire

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

4.7 Length

This document is intended for, but not limited to, applications with a maximum length of 131 ft (40 m).

5. NETWORK PARAMETERS

5.1 Network Topology

The network interconnect shall use a common or global bus. There is no restriction on the length between each Electronic Control Unit, but the total length of the network datalink (total length = A+B+C+D+E+F) shall not exceed 131 ft (40 m).

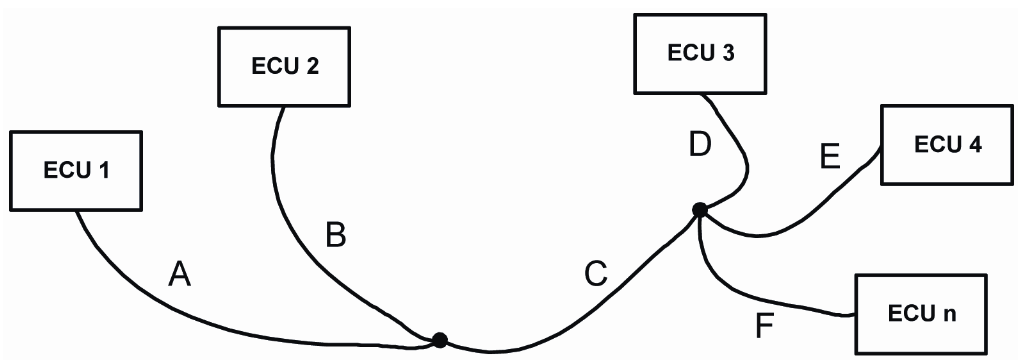

FIGURE 1 - NETWORK TOPOLOGY

5.2 Network Access

The method of access to the network is random.

5.2.1 Idle Line - Bus Synchronization by a Receiver

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).

EXAMPLE: A Receiver that has just connected to the data link will not know the current message strings being broadcast. The goal of the Receiver is to find an Idle Line, so the MID character of the next string can be determined. The Receiver could see the reception of all high-logic levels as shown in "Worst Case Character Time bit map" in Figure 2 in 5.2.2.3. In this case, there would be 8 high-logic level data bit times, 1 high-logic level for the stop bit, and up to 2 high-logic level inter-character bit times. This means that 11 bit times at high-logic level define the start of a new character, but not necessarily a MID character. If the next logic level seen by the Receiver is a low logic level, then another Character Time will follow and the Bus Synchronization must start over. If the next logic level seen by the Receiver is a high-logic level, then an Idle Line may have been identified. If, as shown in Figure 2, there was a Start Bit at the beginning of the 12 bit times, then a true Idle Line time has not occurred. The receiver will not see a start bit until a total of 19 high-logic levels plus the product of 2 bit times and the message priority (which ranges from 1 to 8) of the next message to be transmitted are seen. However, if the receiver did not see the first bit in the Figure 2 "Worst Case Character Time bit map" row, that is the Start bit shown at the far left, then it would have to assume that the string of 12 high-logic levels could be a valid Idle Line and therefore, the next low-logic level would be the start bit of a MID. When the next low-logic level is seen the receiver can assume that it has achieved Bus Synchronization.

5.2.2 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.

5.2.2.1 Bus Access Verification

The transmitter must verify that the idle state continues to exist immediately prior to initiating a transmission. The time between the bus being verified while in the idle state (bus access verification) and the initiation of a transmission shall be less than one-half bit time.

5.2.2.2 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:

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

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

TABLE 1 - BUS ACCESS TIME

T_a	T_i	T_b	P
12 Bit times	10 Bit times	1 Bit time	1
14 Bit times	10 Bit times	1 Bit time	2
16 Bit times	10 Bit times	1 Bit time	3
18 Bit times	10 Bit times	1 Bit time	4
20 Bit times	10 Bit times	1 Bit time	5
22 Bit times	10 Bit times	1 Bit time	6
24 Bit times	10 Bit times	1 Bit time	7
26 Bit times	10 Bit times	1 Bit time	8

5.2.2.3 Bus Access Time Synchronization by a Transmitter

The minimum time duration of an idle line is defined in 3.9. However, a transmitter that cannot distinguish between a stop bit and any other high-logic state may not assume that T_i has elapsed until it has received 19 consecutive high-logic bits.

EXAMPLE: A Transmitter that has just connected to the data link will not know the current message strings being broadcast. The goal of the Transmitter is to find an Idle Line, so message transmission can be initiated. The Transmitter could see the occurrence of all high-logic levels as shown in "Worst Case Character Time bit map" in Figure 2. In this case, there would be 8 high logic level data bit times, 1 high-logic level for the stop bit, and up to 2 high-logic level inter-character bit times. This means that 11 bit times at high-logic level define the start of a new character, but not necessarily a MID character. If the next logic level seen by the Transmitter is a low-logic level, then another Character Time will follow and the Bus Access Time Synchronization must start over. If the next eight logic levels seen by the Transmitter are high-logic levels, then Ti must have elapsed, and now the transmitter still must wait a time duration equal to the product of 2 bit times and the message priority (which ranges from 1 to 8) before beginning its message transmission.

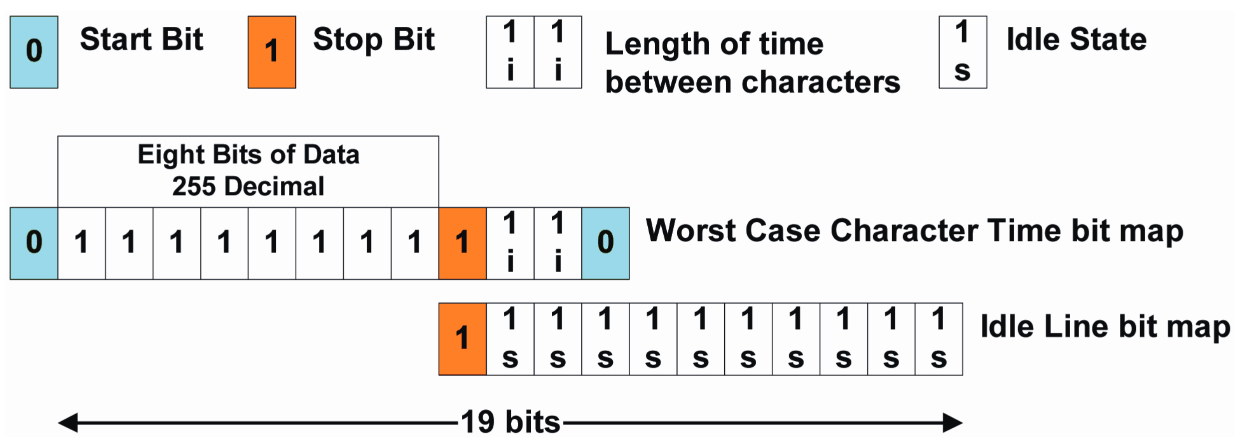

FIGURE 2 - EXAMPLE BUS ACCESS TIME SYNCHRONIZATION

5.2.2.4 Message Priority Assignment

All messages will be assigned a priority from 1 to 8 as indicated in Table 2:

TABLE 2 - MESSAGE PRIORITY ASSIGNMENT

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

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.

5.2.3 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.

6. PROTOCOL

6.1 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.

6.2 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.

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

6.3 Message Format

6.3.1 Message Content

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

a. Message Identification Character (MID)

b. Data Characters

c. Checksum

Example messages:

Shortest Message: MID Checksum
Single data string: MID Data1 Checksum
Multiple data string: MID Data1 Data2 Data3 Data(n) Checksum

As indicated in 5.2, a message shall always be preceded by an idle state of duration equal to or greater than the appropriate bus access time.

6.3.2 Inter-Character Bit Time

The length of time between characters within a message shall not exceed 2 bit times. The minimum length of time between characters within a message can be zero bit times.

6.3.3 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.

6.3.3.1 MID Assignments

The MIDs 0 to 68 shall be assigned to transmitter categories as identified in Table 3. 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 10 and 11 shall be used for trailer ABS Power Line Carrier (PLC) communications. See SAE J2497 Power Line Carrier Communications for Commercial Vehicles.

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

MID 87 is defined in SAE J2497 Power Line Carrier Communications for Commercial Vehicles.

MIDs 88 to 110 shall be allocated as reserved MIDs for transmitter categories beyond those that are identified in Table 3. These MIDs shall be individually assigned by the SAE Low Speed Communications Network Subcommittee of the SAE Truck and Bus Electrical and Electronic 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.

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. MID 125 has been assigned within SAE J2497 only and still retains its existing use on J1708 networks. MID 125 is still unassigned on J1708 networks. MIDs are available to any manufacturer or user for any message identification purpose outside the scope of this document.

MIDs in the range of 128 to 255 shall be reserved for applications using formatted data as set forth in the SAE J1587 document issued by the SAE Low Speed Communications Network Subcommittee. These MIDs shall only be used when the data format set forth within that document is strictly followed (see SAE J1587).

TABLE 3 - MESSAGE IDENTIFICATION CHARACTER ALLOCATION

Message Range	Transmitter Category
00-07	ENGINE
08-09	BRAKES, TRACTOR
10-11	BRAKES, TRAILER (USED BY SAE J2497)
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	SET ASIDE FOR SAE J2497
88-110	DEFINED BY SAE LOW SPEED COMMUNICATIONS NETWORK SUBCOMMITTEE
111	RESERVED--FACTORY ELECTRONIC MODULE TESTER (OFF VEHICLE)
112-124	UNASSIGNED—AVAILABLE FOR USE
125	UNASSIGNED—AVAILABLE FOR USE IN SAE J1708 (PLC IDENTIFCATION as assigned in SAE J2497)
126-127	UNASSIGNED—AVAILABLE FOR USE
128-255	DEFINED BY SAE LOW SPEED COMMUNICATIONS NETWORK SUBCOMMITTEE (see SAE J1587)

6.3.3.2 MID Definitions

MIDs in the 0 to 9, 12 to 68 and 88 to 127 ranges shall be defined in the manufacturer's applications document. Content and format of the data within these messages is not defined in this document but should be identified in a manufacturer's applications document as described in Section 2. If the application will interface with a PLC based system, then SAE J2497 should be consulted before using any MIDs in the above range. 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.

6.3.4 Data Characters

Data characters shall be characters that convey the intelligence of the message and shall conform to the character format as defined in 6.2. 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.

6.3.5 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.

6.3.6 Message Length

Total message length, including MID and checksum, shall not exceed 21 characters.

6.3.7 Message Length Exceptions

a. The 21 byte length limitation may be exceeded when the engine is not running and the vehicle is not moving.

b. 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.

7. NOTES

7.1 Marginal Indicia

A change bar (l) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

PREPARED BY THE SAE LOW SPEED NETWORK COMMUNICATIONS COMMITTEE
OF THE SAE TRUCK AND BUS ELECTRICAL AND ELECTRONICS STEERING COMMITTEE

APPENDIX A - SERIAL DATA BUS STANDARD NODE (UNIPOLAR DRIVE WITH PASSIVE TERMINATION IN EACH MODULE)

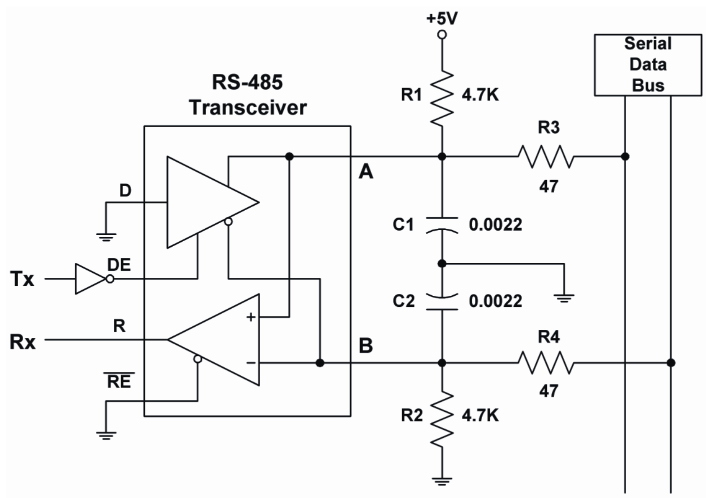

FIGURE A1 - SERIAL DATA BUS STANDARD NODE DIAGRAM

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 previous 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 1 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 ms at the receiver with two nodes on the bus and 2.3 ms with 20 nodes on the bus.

A.6 The passive (low-to-high) transition delay at the receiver remains at 10 ms 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 0 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 5.2.2).

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 5.2.1 but with the bus access time calculated as follows:

$$T_a = T_i + [2 * T_b] * [P_2 + 1] \quad \text{(Eq. B1)}$$

where:

T_i and T_b are defined as in 5.2.1.1

P_2 = A three-bit pseudo 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 previous method would greatly reduce the possibility of a third crash with the same device or devices.