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LIN Network for Vehicle Applications

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Foreword

The objective of this document is to define a level of standardization in the implementation of low speed vehicle serial data network communications using the Local Interconnect Network (LIN) protocol.

The goal of this document is to define a serial data physical layer, data link layer and media design criteria to be installed in various automotive Electronic Control Units (ECU). This standard will allow ECU and tool manufacturers to satisfy the needs of multiple end users with minimum modifications to the basic design. This standard will benefit vehicle Original Equipment Manufacturers (OEMs) by achieving lower ECU costs due to higher industry volumes of the basic design.

NOTE—Understanding of this document requires a working knowledge of the LIN 2.0 Specification Package.

1. Scope of Document

This document covers the requirements for SAE implementations based on LIN 2.0. Requirements stated in this document will provide a minimum standard level of performance to which all compatible ECUs and media shall be designed. This will assure full serial data communication among all connected devices regardless of supplier.

The goal of SAE J2602 is to improve the interoperability and interchangeability of LIN devices within a network by resolving those LIN 2.0 requirements that are ambiguous, conflicting, or optional. Moreover, SAE J2602 provides additional requirements that are not present in LIN 2.0 (e.g., fault tolerant operation, network topology, etc.).

This document is to be referenced by the particular vehicle OEM component technical specification that describes any given ECU in which the single wire data link controller and physical layer interface is located. Primarily, the performance of the physical layer is specified in this document. ECU environmental and other requirements, when provided in the component technical specification, shall supercede the requirements of this document.

The intended audience includes, but is not limited to, ECU suppliers, LIN controller suppliers, LIN transceiver suppliers, component release engineers and vehicle system engineers.

1.1 Rationale

During the development of the Conformance test (J2602-2) for J2602 some issues were found which we have decided to correct. These include the following:

1. Section 3.1 – Added definitions for Command Frame and Request Frame.
2. Section 5.3 – It was decided that the Master device should detect errors and stop transmitting when an error is detected during the message header. This will simplify the Master software and will make the behavior of the bus more predictable.
3. Section 5.4.1 – The names of the errors in this section did not match the names of the errors in Sections 5.8.5.1.3-6 where they are described. They will now match.
4. Section 5.4.3 – The spec now explicitly states that if the sync byte data received by the slave is not correct the slave shall set an error code and ignore the rest of the message.
5. Section 5.5 - $T_{Frame\_Maximum}$ was used twice for the range, the first time it should have been $T_{Frame\_Minimum}$.

6. Section 5.7.2.5 – The Broadcast message IDs mapping has been clarified.
7. Section 5.7.3 – Added additional requirements for device behavior when a Targeted Reset command is received to make the behavior more predictable.
8. Section 5.8.2 – Added a note about signal consistency in the J2602 Status Byte.
9. New Section 5.8.4 – Inserted between 5.8.3 and old 5.8.4. Define repeat usage of signals in frames.
10. Section 5.8.6.1.3 – Tx Bit Error has been changed to Data Error to include the case where a slave receives a data byte other than $55 for the sync byte.
11. Section 5.8.6.2.1 – This section has been added to define a use for APINFO4. This bit has now been defined to indicate that the Slave application is requesting service from the Master.
12. Section 6.3 – Refers to J2602-3 for API requirements.
13. Section 7.2.1 – The wake-up pulses sent by the slave had minimum times between repeats, but no maximum times. This has been addressed.
14. Section 7.12.2 – Additional information has been added as to the behavior of the system during an over-voltage event.

1.2 Mission/Theme

This serial data link network is intended for use in applications where high data rate is not required and a lower data rate can achieve cost reductions in both the physical media components and in the microprocessor and/or dedicated logic devices (ASICs) which use the network.

1.3 Overview

LIN is a single wire, low cost, Class A communication protocol. LIN is a master-slave protocol, and utilizes the basic functionality of most Universal Asynchronous Receiver Transmitter (UART) or Serial Communication Interface (SCI) devices as the protocol controllers in both Master and Slave devices. To meet the target of “Lower cost than either an OEM proprietary communications link or CAN link” for low speed data transfer requirements, a single wire transmission media based on the ISO 9141 specification was chosen. The protocol is implemented around a UART/SCI capability set, because the silicon footprint is small (lower cost). Many small microprocessors are equipped with either a UART or SCI interface (lower cost), and the software interface to these devices is relatively simple to implement (lower software cost). Finally, the relatively simplistic nature of the protocol controller (UART/SCI) and the nature of state-based operation, enable the creation of Application Specific Integrated Circuits (ASICs) to perform as input sensor gathering and actuator output controlling devices, in the vein of Mechatronics.

All message traffic on the bus is initiated by the Master device. Slave devices receive commands and respond to requests from the Master. Since the Master initiates all bus traffic, it follows that the Slaves cannot communicate unless requested by the Master. However, Slave devices can generate a bus wakeup, if their inherent functionality requires this feature.

The “LIN Consortium” developed the set of LIN specifications. The Consortium is a group of automotive OEMs, semiconductor manufacturers, and communication software and tool developers. The LIN specification set is “released” by the LIN Steering Committee, a closed subset of the members. Associate Consortium members contribute to the formation of the specifications through participation in LIN Work Groups; however, the direction of the Work Groups and the final released content of the specifications is the responsibility of the LIN Steering Committee.

The LIN Specifications contain more than just a definition of the LIN protocol and physical layer. In addition, a Work Flow Process, Diagnostics and Configuration methods, definition of an Application Program Interface (API), file structures for a Node Capability File (NCF) and a LIN Description File (LDF) and semantics are identified as required (mandatory in all implementations). However, since there is a great deal of flexibility in the protocol and physical layer, applicability of these specifications to J2602 networks will be further specified in this document.

1.4 Relationship to the LIN Specifications (ref Section 2.6, LIN 2.0 Specification Package)

As described in the LIN Specification Package, the LIN 2.0 protocol specification suite consists of seven documents:

1.4.1 LIN SPECIFICATION PACKAGE

The **LIN Specification Package** provides an overview of the LIN Protocol, its features, and work flow. This includes the Revision History, LIN Overview and Glossary.

1.4.2 LIN PHYSICAL LAYER SPECIFICATION

The **LIN Physical Layer Specification** describes the physical layer, including bit rate, clock tolerances, etc.

1.4.3 LIN PROTOCOL SPECIFICATION

The **LIN Protocol Specification** describes the data link layer of LIN.

1.4.4 LIN DIAGNOSTIC AND CONFIGURATION SPECIFICATION

The **LIN Diagnostic and Configuration Specification** describes the services that can/may be layered on top of the data link layer to provide for diagnostic messages and node configuration.

1.4.5 LIN API SPECIFICATION

The **LIN API Specification** describes the interface between the network and the application program, including the diagnostic module.

1.4.6 LIN CONFIGURATION LANGUAGE SPECIFICATION

The **LIN Configuration Language Specification** describes the format of the LIN description file, which is used to configure the complete network and serve as a common interface between the OEM and the suppliers of the different network nodes, as well as an input to development and analysis tools.

1.4.7 LIN NODE CAPABILITY LANGUAGE SPECIFICATION

The **LIN Node Capability Language Specification** describes a format used to describe off-the-shelf slave nodes that can be used with a system definition tool to automatically create LIN Description Files.

The remainder of this document (SAE J2602) will directly reference these LIN specifications.

2. References

2.1 Applicable Publications

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

2.1.1 SAE Publications

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001 or www.sae.org.

SAE J551—All Parts—Performance Levels and Methods of Measurement of Electromagnetic Compatibility for Vehicles and Devices
SAE J1113—All parts—Electromagnetic Compatibility Measurement Procedures for Vehicle Components
SAE J1213-1—Glossary of Vehicle Networks for Multiplexing and Data Communication
SAE J1930—Electrical/Electronic Systems Diagnostic Terms, Definitions, Abbreviation and Acronyms

2.1.2 ISO Documents

Available from ANSI, 25 West 43rd Street, New York, NY 10036-8002 or www.iso.org.

ISO 7498—Data processing systems, open systems interconnection standard reference mode
ISO 7637—Road vehicles—Electrical interference by conduction and coupling—Parts 1 and 2
ISO 9141—Road vehicles—Diagnostic systems—Requirements for interchange of digital information

2.1.3 Supplier Publications

See Appendix A for list of supplier documents/devices.

2.1.4 Other Publications

LIN Specification Package version 2.0 dated September 23, 2003 available at www.lin-subbus.org.
CISPR 25—Limits and Methods of Measurement of Radio Disturbance Characteristics for the Protection of Receivers Used on Board Vehicles available at webstore.iec.ch.
ES-XW7T-1A278-AC—Ford Component and Subsystem Electromagnetic Compatibility Worldwide Requirements and Test Procedures available at www.fordemc.com. This document shall be referred to as the Ford EMC Spec.

3. Definition of Terms

3.1 Glossary

3.1.1 Command Frame

A frame with data published by the slave task in the Master Node and subscribed to by one or more slave tasks in slave nodes.

3.1.2 DATA LINK LAYER

This provides for the reliable transfer of information across the physical layer. It includes the message structure, framing and error control.

3.1.3 DOMINANT SIGNAL

The driven and low voltage state of the LIN bus. If multiple devices access the bus, this state dominates the recessive or non-driven state.

3.1.4 "DORMANT" STATE

The state in which the slave task state machine is waiting for reception of the Break / Synch sequence.

3.1.5 MASTER NODE

Responsible for initiating all message traffic. See the Glossary of the LIN Specification Package for additional information.

3.1.6 MEDIA

The physical entity that conveys the electrical (or equivalent means of communication) signal transmission among ECUs on the network.

3.1.7 PHYSICAL LAYER

This ISO 7498 subsection consists of the media, mechanical interconnections, and transceivers that provide the interconnection between all ECU nodes.

3.1.8 PROTOCOL

The formal set of conventions or rules for the exchange of information among the ECUs. This includes the specification of the signal frame administration, frame transfer and physical layer.

3.1.9 PUBLISHER

A Master or Slave Node that is the source of the data transmitted onto the bus within a LIN message.

3.1.10 RADIATED EMISSIONS

The energy that radiates from the LIN physical layer.

3.1.11 RADIATED IMMUNITY

The level of susceptibility of physical layer components to communication errors in the presence of high energy electromagnetic fields.

3.1.12 RECESSIVE SIGNAL

The undriven and high voltage state of the LIN bus. If multiple devices access the bus, this state is overridden by the dominant state.

3.1.13 REQUEST FRAME

A frame with data published by the slave task in one and only one Slave Node and only subscribed to by the slave task in the Master Node.

3.1.14 SLAVE NODE

A device that receives messages from the Master Node, or responds to messages initiated by the Master Node. See the Glossary of the LIN Specification Package for additional information.

3.1.15 SUBSCRIBER

A Master or Slave Node that receives the data within a LIN message.

4. Acronyms, Abbreviations, and Symbols

API – Application Program Interface
ASIC – Application Specific Integrated Circuit
CAN – Controller Area Network
DLC – Diagnostic Link Connector
DNN – Device Node Number
ECU – Electronic Control Unit
EMC – Electromagnetic Compatibility
ESD – Electrostatic Discharge
ISO – International Organization for Standardization
Kbits/sec – Thousands of data bits per second

LDF – LIN Description File
LIN – Local Interconnect Network
LSB – Least Significant Byte
lsb – least significant bit
MSB – Most Significant Byte
msb – most significant bit
NAD – Node Address for Diagnostics
NCF – Node Capability File
OEM – Original Equipment Manufacturer
RE – Radiated Emissions
RI – Radiated Immunity
SAE – Society of Automotive Engineers
SCI – Serial Communication Interface
UART – Universal Asynchronous Receiver/Transmitter

5. LIN System Requirements

All ECU LIN interfaces shall conform to the LIN Specification Package of September 2003 unless otherwise specified in this specification.

5.1 LIN Specification Package

The LIN Specification Package as described in Section 1.4.1 LIN Specification Package is informative only and contains no formal requirements. Also note that the information contained in this section of LIN 2.0 may or may not be representative of J2602-based implementations. However, the Glossary included in this section of the LIN specification contains definitions and terms needed to comprehend the LIN Protocol and J2602.

5.2 J2602 Serial Data Link Characteristics

1. Master/Slave Collision Avoidance
2. Capable of operating with LIN 2.0 and previous devices.
3. Additional definition to meet SAE requirements for serial data communication networks.
4. Slave-to-slave communication is not supported and is highly discouraged.

5.3 Detection of Errors by Master (ref Section 4.1, LIN 2.0 Protocol Specification)

The master task state machine shall detect errors during the transmission of the Break / Synch / Protected ID sequence. If an error is detected (e.g., data mismatch or data not received), the master shall cease transmission of the frame and shall start transmission of the next frame as dictated by the schedule table.

5.4 Frame Processing by Slave Tasks (ref Section 4.2.2, LIN 2.0 Protocol Specification)

5.4.1 SLAVE TASK ERROR DETECTION

The slave task state machine (either in a slave node or the master) shall detect the following errors:

- ID Parity Error
- Byte Field Framing Error (i.e., invalid stop bit)
- Data Error (i.e., data transmitted does not match data read, data transmitted is not received, fixed form data received is incorrect)
- Checksum Error

5.4.2 SLAVE BEHAVIOR IN THE PRESENCE OF ERRORS WHEN TRANSMITTING

When a slave task state machine detects a Byte Field Framing Error, Data Error, or Checksum Error, the slave task state machine shall cease transmission prior to transmission of the next byte field, unless the error occurs during the transmission of the Checksum byte, and return to the "Dormant" state. The slave task shall also set the appropriate error flags as defined in Section 5.8.6 (J2602 Status Byte).

5.4.3 SLAVE BEHAVIOR IN THE PRESENCE OF ERRORS WHEN RECEIVING

When a slave task machine detects an ID Parity Error, Byte Field Framing Error, Data Error or Checksum Error, the slave task state machine shall discard any data buffered from the current frame and return to the "Dormant" state. The slave task shall also set the appropriate error flags as defined in Section 5.8.6 (J2602 Status Byte).

5.5 Message Transmission Time Tolerance (ref. Section 2.2, LIN 2.0 Protocol Specification)

Each maximum message transmission time may be specified to be within the range of $T_{Frame\_Minimum}$ and $T_{Frame\_Maximum}$, providing both publisher and subscriber of the frame support a maximum message transmission time of less than $T_{Frame\_Maximum}$.

The minimum $T_{Frame\_Maximum}$ value to which a slave node can respond shall be identified in its Node Capability File. In the event a value is not provided in the Node Capability File, the Master node shall presume a value of $T_{Frame\_Maximum}$ as defined in the LIN 2.0 Protocol Specification.

5.6 LIN Product Identification (ref. Section 2.4, LIN 2.0 Diag and Config Specification)

The following requirements provide further clarification to the intent of the LIN Function ID and Variant ID assignment conditions.

5.6.1 CLARIFICATION TO FUNCTION ID PARAGRAPH:

Two products (ECUs) are identical in function and shall be assigned identical Function Identifiers if they exhibit all of the following characteristics:

- They exhibit identical functional behavior
- They exhibit identical mandatory Node Capability File declarations
- Both LIN communications and Application functionality are configured identically by the IC supplier

5.6.2 CLARIFICATION TO VARIANT ID PARAGRAPH:

Two products (ECUs) are invariant and shall be assigned identical Variant Identifiers if they exhibit all of the following characteristics:

- They have identical operating range characteristics (voltage, temperature)
- They are constructed from the identical integrated circuit processes and manufacturing technology

NOTE—Any change in the binary image loaded in a microprocessor-based slave implementation shall constitute a difference in the variant ID.

5.7 Mandatory Node Configuration Requests (ref. LIN 2.0 Diag and Config Specification)

These messages are to be used for configuration only; they are not to be used for LIN diagnostics since all relevant diagnostic information is included in the J2602 Status Byte. Furthermore, these configuration messages are only initiated by the master; they are not initiated through the J1962 connector since the LIN bus does not go to this connector.

Support of diagnostics and configuration as defined in the LIN Diagnostic and Configuration Specification in the LIN 2.0 Specification Package is **OPTIONAL** in J2602 nodes. In other words, support of the services defined as mandatory in Section 2.5 of the LIN Diagnostic and Configuration Specification is optional and is **NOT** required for J2602 compliance.

The following sections define the required SAE J2602 node configuration command/response messages.

5.7.1 GENERAL CONFIGURATION REQUIREMENTS

5.7.1.1 Slave Execution of Configuration

Within the limit of its capabilities, a slave device shall immediately execute any configuration command upon receipt of the $3C message; it shall not wait for a $3D message.

5.7.1.2 Slave Device Configuration Capabilities

A NCF file shall be included with a SAE J2602 device.

5.7.1.3 Master Configuration Message Pairing

A master shall always transmit $3C / $3D coupled pairs. The master shall never send multiple successive $3C messages without corresponding (interleaved) $3D messages. There shall be exactly one $3D response for each $3C command. The only exception to this is in the case of a broadcast $3C message which shall have no corresponding $3D message.

5.7.2 NAD AND MESSAGE ID ASSIGNMENT

5.7.2.1 NAD Assignment

The NAD for a J2602 device shall be in the range $60 to $6D, where the lower nibble of the J2602 NAD contains a four bit Device Node Number (DNN). An uninitialized node shall have a NAD of $6F. A NAD of $6E may be used; however, its message IDs must be assigned via $3C or $3E messages.

IC manufacturers may provide the ability to select the desired Device Node Number, and hence the NAD, based on up to four memory bits, four external pins, etc. These bits or pins shall only impact the value of the lower nibble of the NAD. If the device has a selectable NAD, it shall default to $6F prior to initialization.

J2602 NAD

Bit 7 (msb)	6	5	4	3	2	1	Bit 0 (lsb)
0	1	1	0	DNN3	DNN2	DNN1	DNN0

5.7.2.2 Message ID Assignment

Each device shall be assigned 4 message ID's based on the DNN, and therefore the NAD. If a device does not need that many messages, it shall use the messages with the lowest ID's. If a device requires more than 4 message ID's, it shall be assigned messages in powers of 2, i.e. 4, 8, 16, 32. The system designer must ensure that multiple devices do not use the same Message ID's.

As a consequence of having the message ID's associated with the DNN, after a power on reset, or reset command the protected identifiers are still marked as valid for devices with a DNN in the range $0 - $D. Devices with a DNN of $E or $F will have the protected identifiers marked as invalid as described in Section 2.1 of the LIN Diagnostic and Configuration Specification.

The following table shows the boundaries for 4, 8, or 16 messages per node. If 32 Message ID's are required, NAD $60 must be used for this node. J2602 networks can combine nodes that use various numbers of Message ID's.

TABLE 1—NAD TO MESSAGE ID MAPPING

NAD	Message ID	NAD	Message ID	NAD	Message ID
$60	$00 $01 $02 $03	$60	$00 $01 $02 $03	$60	$00 $01 $02 $03
$61	$04 $05 $06 $07		$04 $05 $06 $07		$04 $05 $06 $07
$62	$08 $09 $0A $0B	$62	$08 $09 $0A $0B		$08 $09 $0A $0B
$63	$0C $0D $0E $0F		$0C $0D $0E $0F		$0C $0D $0E $0F
$64	$10 $11 $12 $13	$64	$10 $11 $12 $13	$64	$10 $11 $12 $13
$65	$14 $15 $16 $17		$14 $15 $16 $17		$14 $15 $16 $17
$66	$18 $19 $1A $1B	$66	$18 $19 $1A $1B		$18 $19 $1A $1B
$67	$1C $1D $1E $1F		$1C $1D $1E $1F		$1C $1D $1E $1F
$68	$20 $21 $22 $23	$68	$20 $21 $22 $23	$68	$20 $21 $22 $23
$69	$24 $25 $26 $27		$24 $25 $26 $27		$24 $25 $26 $27
$6A	$28 $29 $2A $2B	$6A	$28 $29 $2A $2B		$28 $29 $2A $2B
$6B	$2C $2D $2E $2F		$2C $2D $2E $2F		$2C $2D $2E $2F
$6C	$30 $31 $32 $33	$6C	$30 $31 $32 $33	$6C	$30 $31 $32 $33
$6D	$34 $35 $36 $37		$34 $35 $36 $37	$6D	$34 $35 $36 $37
$6E	No Message IDs defined	$6E	No Message IDs defined	$6E	No Message IDs defined
$6F	No Message IDs defined	$6F	No Message IDs defined	$6F	No Message IDs defined

NOTE—The Message IDs listed in this table are the unprotected Identifiers.

5.7.2.3 Configuration Messages

LIN protocol level and application level configuration of each slave node may be accomplished using any combination of the following:

1. Using optional method defined in the LIN Diagnostic and Configuration Specification in the LIN 2.0 Specification Package.
2. Using $3C messages with NADs in the User reserved range of $80 - $FF.
3. Using $3E messages with any NAD.

When using $3C or $3E messages to configure the slaves, the lower nibble of the NAD shall be the DNN to prevent conflicts between slaves.

$3C NAD

Bit 7 (msb)	6	5	4	3	2	1	Bit 0 (lsb)
1	X	X	X	DNN3	DNN2	DNN1	DNN0

$3E NAD

Bit 7 (msb)	6	5	4	3	2	1	Bit 0 (lsb)
X	X	X	X	DNN3	DNN2	DNN1	DNN0

5.7.2.4 Response Message to Options 2 and 3 in Section 5.7.2.3

The $3D Response message that follows each $3C and $3E Command message shall return the J2602 Status Byte (defined in Section 5.8.6) in Data Byte 0. The value of the other seven data bytes is implementation dependent and beyond the scope of this specification.

Tx by Master	*Tx by Slave*	*Tx by Slave*	*Tx by Slave*	*Tx by Slave*	*Tx by Slave*	*Tx by Slave*	*Tx by Slave*	*Tx by Slave*
LIN ID	Data0	Data1	Data2	Data3	Data4	Data5	Data6	Data7
$3D	J2602 Status Byte	XX	XX	XX	XX	XX	XX	XX

5.7.2.5 DNN Based Broadcast Messages

There are four Message IDs reserved for Broadcast messages. The NAD that will use a specific Broadcast Message, and the data byte within the message that it will use is based on its DNN. The Broadcast Message IDs for a specific NAD are b11 100x and b11 101x, where x = DNN3. The relevant data byte number is equivalent to the three lsbs of the DNN. In the case where a node has more than 4 message IDs, i.e. 8 or 16, it shall also be assigned a proportionate number of Broadcast Message bytes.

5.7.2.5.1 DNN Based Broadcast Message Assignment for 4 Messages per Node

LIN ID	Data0	Data1	Data2	Data3	Data4	Data5	Data6	Data7
$38	DNN = $0	DNN = $1	DNN = $2	DNN = $3	DNN = $4	DNN = $5	DNN = $6	DNN = $7
$39	DNN = $8	DNN = $9	DNN = $A	DNN = $B	DNN = $C	DNN = $D	XX	XX
$3A	DNN = $0	DNN = $1	DNN = $2	DNN = $3	DNN = $4	DNN = $5	DNN = $6	DNN = $7
$3B	DNN = $8	DNN = $9	DNN = $A	DNN = $B	DNN = $C	DNN = $D	XX	XX

5.7.2.5.2 DNN Based Broadcast Message Assignment for 8 Messages per Node

LIN ID	Data0	Data1	Data2	Data3	Data4	Data5	Data6	Data7
$38	DNN = $0	DNN = $0	DNN = $2	DNN = $2	DNN = $4	DNN = $4	DNN = $6	DNN = $6
$39	DNN = $8	DNN = $8	DNN = $A	DNN = $A	DNN = $C	DNN = $C	XX	XX
$3A	DNN = $0	DNN = $0	DNN = $2	DNN = $2	DNN = $4	DNN = $4	DNN = $6	DNN = $6
$3B	DNN = $8	DNN = $8	DNN = $A	DNN = $A	DNN = $C	DNN = $C	XX	XX

5.7.2.5.3 DNN Based Broadcast Message Assignment for 16 Messages per Node

LIN ID	Data0	Data1	Data2	Data3	Data4	Data5	Data6	Data7
$38	DNN = $0	DNN = $0	DNN = $0	DNN = $0	DNN = $4	DNN = $4	DNN = $4	DNN = $4
$39	DNN = $8	DNN = $8	DNN = $8	DNN = $8	DNN = $C	DNN = $D	XX	XX
$3A	DNN = $0	DNN = $0	DNN = $0	DNN = $0	DNN = $4	DNN = $4	DNN = $4	DNN = $4
$3B	DNN = $8	DNN = $8	DNN = $8	DNN = $8	DNN = $C	DNN = $D	XX	XX

5.7.3 TARGETED RESET

The Targeted Reset command provides a mechanism for the Master to cause a re-initialization of a specific slave device on the network, designated by the NAD in the command. Upon receipt of the Targeted Reset command, the slave device shall cause an internal reset of operational variables to occur. Examples of operational variables include, but are not limited to, program counters, mode control variables, communications error counters, input source re-initializations, and output device re-initializations, but shall not alter any previously configured application level configuration information stored in non-volatile memory. This Reset operation shall not cause the slave to destructively alter any LIN configuration data or addresses stored in non-volatile memory. Also, the Reset operation shall not cause any configuration parameters in the LIN Data Link device (UART) to be altered. Upon conclusion of the Reset operation, the slave device shall remain configured, and shall assume a state consistent with a power-on initialization, with the exception of the LIN configuration information. The slave shall also retain knowledge that it has undergone a reset operation, such that a positive response can be provided to the Master.

The LIN Slave device shall be able to respond to a $3D request frame which starts immediately after the stop bit of the checksum byte of the $3C Targeted Reset command frame.

For those devices that are always in the power-on state, i.e. input only devices, a Reset Command may have no impact on the device state; however, this device shall still set the reset flag within the J2602 status byte and shall send a positive response.

A device may elect not to perform the requested Reset command based on the application program requirements. In this case, the device will respond with a Negative Response.

5.7.3.1 Command

Tx by Master	*Tx by Master*	*Tx by Master*	*Tx by Master*	*Tx by Master*	*Tx by Master*	*Tx by Master*	*Tx by Master*	*Tx by Master*
LIN ID	Data0 NAD	Data1 PCI	Data2 SID	Data3	Data4	Data5	Data6	Data7
$3C	NAD	$01	$B5	$FF	$FF	$FF	$FF	$FF

5.7.3.2 Positive Response

Tx by Master	*Tx by Slave*	*Tx by Slave*	*Tx by Slave*	*Tx by Slave*	*Tx by Slave*	*Tx by Slave*	*Tx by Slave*	*Tx by Slave*
LIN ID	Data0 NAD	Data1 PCI	Data2 RSID	Data3	Data4	Data5	Data6	Data7
$3D	NAD	$06	$F5	Supplier ID LSB	Supplier ID MSB	Function ID LSB	Function ID MSB	Variant ID

5.7.3.3 Negative Response

Tx by Master	*Tx by Slave*	*Tx by Slave*	*Tx by Slave*	*Tx by Slave*	*Tx by Slave*	*Tx by Slave*	*Tx by Slave*	*Tx by Slave*
LIN ID	Data0 NAD	Data1 PCI	Data2 RSID	Data3	Data4	Data5	Data6	Data7
$3D	NAD	$06	$7F	Supplier ID LSB	Supplier ID MSB	Function ID LSB	Function ID MSB	Variant ID

5.7.4 BROADCAST RESET

Device behavior when a Broadcast Reset Command is received shall be the same as the behavior when a Targeted Reset Command is received.

5.7.4.1 Command

Tx by Master	*Tx by Master*	*Tx by Master*	*Tx by Master*	*Tx by Master*	*Tx by Master*	*Tx by Master*	*Tx by Master*	*Tx by Master*
LIN ID	Data0 NAD	Data1 PCI	Data2 SID	Data3	Data4	Data5	Data6	Data7
$3C	$7F	$01	$B5	$FF	$FF	$FF	$FF	$FF

5.7.4.2 Response

There shall be no positive or negative response to this command. Positive acknowledgment of this message can be ascertained via the reset bit in the J2602 Status Byte.

5.8 Message Format

5.8.1 CHECKSUM (REF. SECTION 2.1.5, LIN 2.0 PROTOCOL SPECIFICATION)

The enhanced checksum method shall be used for all protected identifiers except for those in the range of $3C to $3F.

5.8.2 SIGNAL CONSISTENCY (REF. SECTION 1.2, LIN 2.0 PROTOCOL SPECIFICATION)

The requirement that all "scalar signal writing or reading must be atomic" is not externally verifiable in all LIN implementations. Consequently this requirement is a guideline.

NOTE—Since there is a very close coupling between the J2602 Error signal and the APPINFO4 signal, implementers of J2602 slave nodes are encouraged to make every effort to publish these two status signals ”with consistency”, so that any/all error signaling between the Slave and the Master can be interpreted properly.

5.8.3 SIGNAL ENCODING TYPES (REF. SECTION 1.1, LIN 2.0 PROTOCOL SPECIFICATION)

Since only two signal encoding types are allowed in the LIN 2.0 protocol specification (scalar and byte array), and there is an expectation to employ other standard signal encoding types commonly used in other serial data implementations, the following recognized signal encoding types shall be mapped into the two LIN signal encoding types in accordance with the following table. Appendix B Signal Encoding Types contains descriptions and examples of each of the signal encoding types listed.

TABLE 2—COMMON SIGNAL ENCODING TYPE MAPPING TO LIN DEFINED DATA ENTITIES

Signal Encoding Type	Slot Type	Mapped to LIN Data Type	Notes
ASCII	ASC	8-bit Scalar	Most Significant Bit reserved and set to "0", ASCII codes 0 through 127
Binary Coded Decimal	BCD	4 bit Scalar per BCD character	Must be on nibble boundaries.
Boolean	BLN	1 bit Scalar	
Enumerated	ENM	N bit Scalar, in increments of 1 bit (1 – 16 bits)	
Signed Floating Point	SFP	4 byte - Byte Array	As defined in ANSI/IEEE Std 754-1985
Signed Numeric	SNM	8, 16, or 32 bit Byte Array	2's Complement notation
Unsigned Numeric	UNM	N bit Scalar, increments of 8 bits (1 byte)	Not to exceed 16 bits (2 bytes)

Note that slave devices may transmit a maximum of 7 data bytes as the first data byte has been reserved for the J2602 Status Byte. The master device may transmit 8 data bytes, as it is not required to transmit the J2602 Status Byte. (See 5.8.6 J2602 Status Byte.)

5.8.4 SIGNAL MANAGEMENT

Signals may belong to multiple frames, e.g. J2602 Status Byte. Signals may also be placed in the same frame multiple times, e.g. Broadcast messages.

5.8.5 UNUSED BITS IN THE DATA FIELD (REF. SECTION 2.3, LIN 2.0 PROTOCOL SPECIFICATION)

The length of each frame in bytes, used for LIN normal communications (not diagnostics or configuration), shall be defined for each LIN network, on a frame-by-frame basis. Any bits of a defined frame that are either not used or not defined shall be transmitted as recessive symbols. Padding of unused data bytes within LIN normal communications messages is not required. That is, normal communications messages may vary in length between 1 byte and 8 bytes.

5.8.6 J2602 STATUS BYTE

This section defines a single standardized format for a J2602 Status Byte, which encompasses both LIN Protocol Error reporting and application specific information.

The J2602 Status Byte contains two enumerated bit fields, a 3 bit error field, and a 5 bit field for application specific information. Only the error field is defined, since it is the only one with the error and status states explicitly defined. The application information field is defined and implemented on a case-by-case basis, dependent on the requirements of each slave node application. The resulting application information field implementation is documented in the NCF for each slave node. This status byte shall be transmitted as the first byte of every slave transmission, where the identifier is in the range of $00 through $3B.

J2602 Status Byte

Bit 7 (msb)	6	5	4	3	2	1	Bit 0 (lsb)
ERR2	ERR1	ERR0	APINFO4	APINFO3	APINFO2	APINFO1	APIFNO0

5.8.6.1 Error Field Definition

ERR[2:0] – Error Field (Bits 7-5)

These bits report the four defined Error States that have been seen by the Slave node since an error state has been last reported to the Master node. The four states, as shown in Table 3 below, are "sticky", which means that they are retained until they are successfully reported to the Master node in a message without any detected errors, after which they are automatically cleared. Only one state may be reported at a time. There is an inherent hierarchy to the states, with the highest latched state reported first. Bit 7 also serves the purpose of the Response_Error bit from LIN Rev. 2.0, Section 6.3.

TABLE 3—ERR STATES

ERR2	ERR1	ERR0	Fault State	Priority
0	0	0	No Detected Fault	0 (lowest)
0	0	1	Reset	1
0	1	0	Reserved	2
0	1	1	Reserved	3
1	0	0	Data Error	4
1	0	1	Checksum Error	5
1	1	0	Byte Field Framing Error	6
1	1	1	ID Parity Error	7 (highest)

5.8.6.1.1 No Detected Fault

A slave node shall indicate this state whenever none of the other detectable fault states are active. This is the default state of the LIN device.

5.8.6.1.2 Reset

A slave node shall set this state upon interruption and resumption of power, after a watchdog timeout, or after receipt of a Reset Command. Note that for those devices that require configuration and store the configuration information in volatile memory, this state indicates that the device is currently unconfigured and requires configuration. For those devices that use non-volatile memory for configuration information storage, then the state indicates configuration is required the first time the part is powered on and only indicates a reset from then on.

5.8.6.1.3 Data Error

A slave or master node that is transmitting a bit on the bus shall also monitor the bus. A Data Error shall be detected when the bit or byte value that is received is different from the bit or byte value that is transmitted.

A slave node that is receiving shall detect a Data Error when the data in the fixed form Sync Byte is received incorrectly, i.e. is not $55. A slave node that performs autobauding shall detect this error but is not required to set the error bit.

5.8.6.1.4 Checksum Error

A Checksum Error shall be detected if the inverted modulo-256 sum over all received data bytes and the protected identifier (when using enhanced checksum) and the received checksum byte field does not result in $FF. (See Section 2.1.5 in the LIN 2.0 Protocol Specification.)

5.8.6.1.5 Byte Field Framing Error

The receiver shall detect a Byte Field Framing Error if the ninth bit after a valid start bit is dominant.

5.8.6.1.6 ID Parity Error

The receiver shall detect an ID Parity Error if the received ID parity (bits 6 & 7) does not match the ID parity calculated from the equations in Section 2.1.3, LIN 2.0 Protocol Specification based on the received identifier (bits 0 – 5).

5.8.6.2 Application Information Field

APINFO[4:0] – Application Information Field (Bits 4-0)

5.8.6.2.1 APINFO4

APINFO4 shall be used to indicate when the application requires attention from the Master Device. This shall be indicated by setting the bit to “1”.

When a Reset state is indicated by the Error Field when this bit is “1” it shall indicate that the device needs to be configured.

The action taken by the Master when this bit is “1” and no Reset state is indicated shall be documented (e.g. in the NCF, datasheet, or Application Note, etc.) and may include loading a special schedule table which queries the Application as to its status.

5.8.6.2.2 APINFO[3:0]

The lower four bits of the application information field are not explicitly defined, since their structure will be dependent on the specific application and implementation of the slave node. This field may be implemented as discrete status bits, a state encoded bit field, or a combination of the two. The clearing mechanism used is also implementation dependent. The explicit definition of the Application Information Field shall be documented (e.g. in the NCF, datasheet, or Application Note, etc.).

5.8.6.2.3 No Application Information to Report

A value of zero (00000b) indicates that no application information currently needs to be reported. All other encodings are application specific and beyond the scope of J2602.

5.9 Message Types

5.9.1 AVAILABILITY OF UNCONDITIONAL FRAMES (REF SECTION 2.3.1, LIN 2.0 PROTOCOL SPECIFICATION)

The requirement that subscribers of an unconditional frame shall make it available to the application is not externally verifiable in all LIN implementations. Consequently this requirement is a guideline.

5.9.2 EVENT TRIGGERED FRAMES (REF. SECTION 2.3.2, LIN 2.0 PROTOCOL SPECIFICATION)

Event Triggered frames shall not be utilized in J2602 compliant LIN networks.

5.9.2.1 Identifier Assignment (J2602 Requirement Resulting from Event Triggered Frame Anomaly)

One and only one slave shall be defined as the publisher to a single frame identifier.

5.9.3 SPORADIC FRAME (REF. SECTION 2.3.3, LIN 2.0 PROTOCOL SPECIFICATION)

Messages of the Sporadic Frame type may be utilized within the J2602 environment, if appropriate. The Master Node shall be the only publisher of Sporadic Frames.

6. J2602 API Requirements

6.1 Master Node Configuration API

For Master implementations, the Node Configuration API (Section 3 of the LIN 2.0 API specification) is mandatory if any Node Configuration commands will be utilized on the network. If Node Configuration is not used, these API calls are optional.

The Node Configuration API only applies to Master implementations.

6.2 Diagnostic Transport Layer API

For Master or Slave implementations, the Diagnostic Transport Layer API (Section 4 of the LIN 2.0 API specification) is optional.

Diagnostic information is supplied via the J2602 Status Byte.

6.3 Additional API Requirements

Please see J2602-3 for additional details on Master and Slave API Requirements.

7. J2602 Bus Operation

The physical layer is responsible for providing a method of transferring digital data symbols (1’s and 0’s) to the communication medium. The physical layer interface is a single wire, vehicle battery referenced bus, with low side voltage drive.

7.1 Normal Communication Mode and Transmission Rate

Transmission bit rate in the normal communication mode is 10.417 Kbits/sec, this results in a nominal bit time of 96 µs. In the normal transmission mode, transmitters with controlled waveform fall and undershoot times should be used. Waveform rising edge control is recommended to assure that high frequency components are minimized at the beginning of the upward voltage slope. The remaining rise time occurs after the bus is inactive with drivers off and is determined by the RC time constant of the total bus load.

7.2 Sleep/Wake Mode

7.2.1 WAKE-UP (REF. SECTION 5.1, LIN 2.0 PROTOCOL SPECIFICATION)

The node may continue to issue wake-up requests until the Master node responds by transmitting a frame identifier. Following a minimum delay of 1.5 seconds and a maximum delay of 3.0 seconds (after the third wake-up attempt), the slave device may initiate one additional sequence of three wake-up requests separated by a minimum of 150 ms and a maximum of 300 ms. The cycle is concluded following the sixth wake-up transmission. The minimum elapsed time for one complete wake-up cycle, as described, is 2.1 seconds.

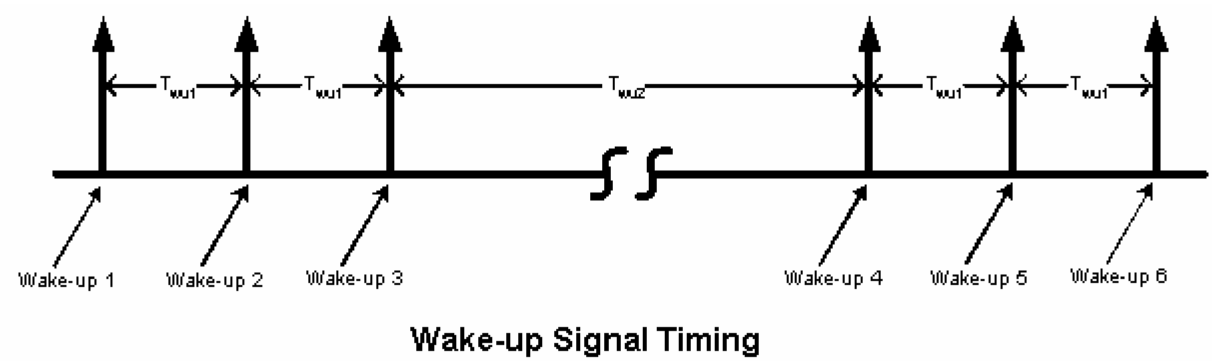

FIGURE 1—WAKE-UP SIGNAL TIMING

Parameter	Minimum	Maximum
Wake-up Pulse	250 µs	5 ms
T_{wu1}	150 ms	300 ms
T_{wu2}	1.5 seconds	3 seconds

If no response (valid identifier transmission) is produced by the Master node in response to the wake-up requests, the slave node shall default to a network sleep state. In the event the slave node detects another local wake-up input after the sleep default, it may again attempt to wake the Master through a new wake-up signal cycle. There is no limit to the number of wake-up cycles that may be attempted.

7.2.2 GO TO SLEEP (REF. SECTION 5.2, LIN 2.0 PROTOCOL SPECIFICATION)

The Master node must transmit an explicit “Go To Sleep” command to the network, prior to ceasing to transmit.

7.2.2.1 Slave Node Sleep

All slave node(s) shall interpret a cessation of all message traffic for four seconds on a given network, without receiving an explicit “Go To Sleep command” as a failure condition of the Master node or the physical layer. When this condition occurs, the slave node(s) shall assume a default state that may include sleep and/or low power consumption state or application defined functionality.

7.3 LIN Controller Clock Tolerance

7.3.1 MASTER-SLAVE COMMUNICATION

TABLE 4—MASTER-SLAVE COMMUNICATION CLOCK TOLERANCE

Device Type	Clock Tolerance	Notes
Master	+/- 0.5%	Initial Tolerance + Divide Error
Slave	+/- 1.5%	From the nominal bit time with a fixed clock → Initial Tolerance + Divide Error when synchronized
Slave (autobauding)	+/- 2.0%	From the master bit time → Initial Tolerance + Divide Error when synchronized

7.3.2 SLAVE-SLAVE COMMUNICATION

This mode is currently not supported and is not recommended. This is for information purposes only.

TABLE 5—MASTER-SLAVE COMMUNICATION CLOCK TOLERANCE

Device Type	Clock Tolerance	Notes
Master	+/- 0.5%	Initial Tolerance + Divide Error
Slaves communicating with Master only.	+/- 1.5%	Initial Tolerance + Divide Error when synchronized
Slaves communicating with Master only. (autobauding)	+/- 2.0%	From the nominal bit time with a fixed clock → Initial Tolerance + Divide Error when synchronized
Slaves communicating with Slave	+/- 1.0%	From the nominal bit time → Initial Tolerance + Divide Error when synchronized (Note: This requires autobauding slaves to synchronize within +/- 0.5% of the master.)

7.4 Bus Electrical Parameters

This section describes the bus electrical voltage level parameters required by devices that drive and receive signals on the LIN bus.

7.4.1 LIN BUS SIGNALS AND LOADING REQUIREMENTS

TABLE 6—LIN BUS SIGNALS AND LOADING REQUIREMENTS

Parameter	Symbol	Min.	Typ.	Max.	Units
ECU Battery Voltage Input [1]	$V_{batt\ ECU}$	8		18	volts
Maximum ECU Battery Voltage Input for no Damage [7]	$V_{batt\ max\ ECU}$	-13		40	volts
IC Battery Voltage Input	$V_{batt\ IC}$	7		18	volts
Maximum IC Battery Voltage Input for no Damage	$V_{batt\ max\ IC}$	0		34	volts
Output High Voltage	V_{oh}	0.8 $V_{batt\ IC}$		$V_{batt\ IC}$	volts
High Voltage (Recessive) Input Threshold	V_{ih}	0.47 $V_{batt\ IC}$		0.6 $V_{batt\ IC}$	volts
Output Low Voltage	V_{ol}	0.0		0.2 $V_{batt\ IC}$	volts
Low Voltage (Dominant) Input Threshold	V_{il}	0.4 $V_{batt\ IC}$		0.53 $V_{batt\ IC}$	volts
Input Threshold Hysteresis (V_{ih} - V_{il}) [6]	V_{HYS}	0.07 $V_{batt\ IC}$		0.175 $V_{batt\ IC}$	volts
Ground Offset Voltage	$V_{g\ off}$	—		0.1 $V_{batt\ ECU}$	volts
Battery ECU Offset Voltage	$V_{b\ off}$	—		0.1 $V_{batt\ ECU}$	volts
LIN bus to Ground Isolation Resistance	$V_{L\text{-}G\ Iso}$	500 K			ohms
Network Total Resistance	R_{tl}	537		1081	ohms
Device Bus Leakage Current V_{batt} Disconnected	$I_{leak\ batt}$	-23		23	µA
Device Bus Leakage Current Ground Disconnected	$I_{leak\ gnd}$	-100		100	µA
Slave Device Capacitance [3]	C_{slave}	90	220	272	pF
Master Device Capacitance [3]	C_{master}	90	680	2450	pF
Network Total Capacitance [4]	C_{tl}	926		9310	pF
Bus Wiring Capacitance	C_w			100	pF/m
Network Time Constant [2]	$\tau_{network}$	1.0		5.0	µs
Master Termination Resistance	R_M	900	1000	1100	ohms
Slave Termination Resistance	R_S	20,000	30,000	60,000	ohms
$t_{REC(MAX)} - t_{DOM(MIN)}$ [5]	$T_{r\text{-}d\ max}$	—		15.9	µsec
$t_{DOM(MAX)} - t_{REC(MIN)}$ [5]	$T_{d\text{-}r\ max}$	—		17.28	µsec
Total Network length connecting all ECU nodes	bus length	—		40 (see Table 7 for application limits)	meters
Number of system nodes		2		16	

1. V_{batt} is measured at the ECU input power pins. All voltages are referenced to the local ECU ground.
2. The normal mode network time constant ($\tau_{network}$) is the product of R_{tl} and C_{ltl}. The network time constant incorporates the bus wiring capacitance. The minimum value is selected to limit radiated emissions. The maximum value is selected to ensure proper communication under all communication modes and is the absolute maximum allowed under normal operating conditions. The system should be designed to have a time constant no larger than 5.3 µs under an error condition at a slave node. This should be considered when determining the fusing for the vehicle. Not all combinations of R and C are possible. Only those combinations of R and C, and bus length, and PCB trace capacitance, etc. are possible that meet the specified network time constant.
3. The ECU capacitance includes the actual load capacitor as well as the PCB trace capacitance, connector capacitance, etc.
4. The Network total capacitance includes the capacitors placed on the ECUs as well as the capacitance of the bus wires.
5. Equations for converting from the Duty Cycle in the LIN Physical Layer Spec Table 3.4 to the times in this table can be found in Appendix C.
6. Input Threshold Hysteresis (V_{ih} - V_{il}) cannot be less than 0.0
7. See Section 7.12 Operating Battery Power Voltage Range for details.

7.5 LIN Data Link (UART) Requirements

Any device (e.g. UART, SCI, software, etc.) chosen to implement a J2602 LIN data link interface shall meet all requirements in this section.

7.5.1 SAMPLE POINT

The device shall sample the data within the window specified in Figure 2. No samples shall be taken outside the specified window for the purpose of determining the value of the data on the bus. The device may take three samples and use the majority to determine the data, or it may take a single sample to determine the data.

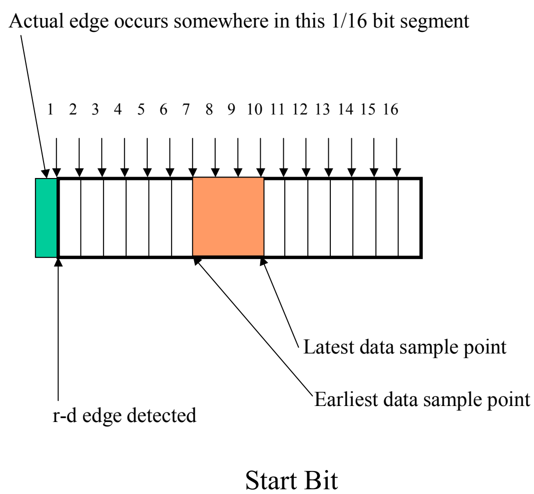

FIGURE 2—BIT SAMPLE TIMING

7.5.2 SYNCHRONIZATION

1. The device shall be able to synchronize within 1/16 of a bit time.
2. The device shall only synchronize on recessive to dominant edges.
3. The device shall always synchronize on the recessive to dominant edge of the Start bit.

7.5.3 TRANSMIT MESSAGE BUFFERING

Double buffering shall not be used for transmit messages to ensure that the requirement for error detection in Section 5.4.2 (Slave Behavior in the Presence of Errors When Transmitting) is not violated.

7.6 LIN ECU Requirements

7.6.1 ECU CIRCUIT REQUIREMENTS

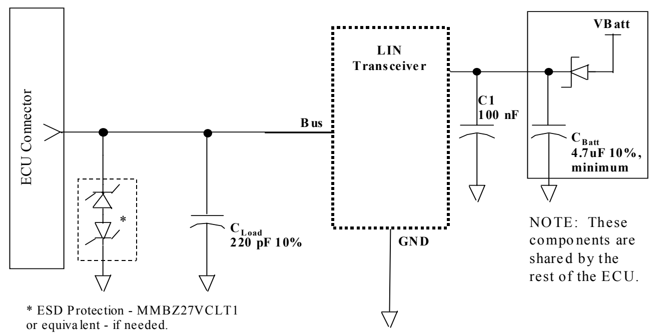

FIGURE 3—TYPICAL LIN SLAVE BUS INTERFACE

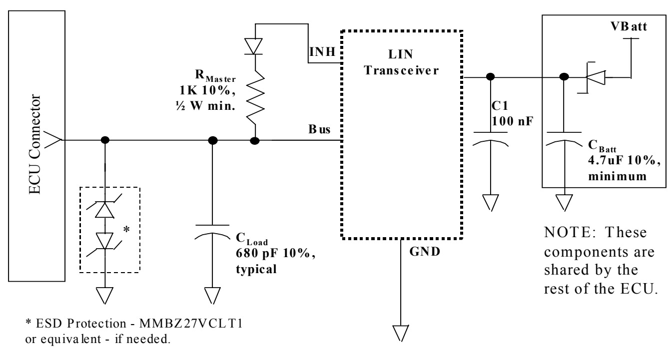

FIGURE 4—TYPICAL LIN MASTER BUS INTERFACE

7.6.1.1 Master Node Resistor

The Master node resistor shall be as specified in Table 6 and Figure 4. It shall have a minimum power rating of 0.5W, or 0.36W at the maximum specified operating temperature.

This assumes that the transceiver limits the current to the load pin to a maximum of 20 mA. In the event the transceiver will provide more current to the resistor, the maximum power dissipation shall be the maximum of 0.78W and that calculated by the following equation: P (watts) = I^2 * R where I is the maximum current in Amps and R is 900 ohms.

7.6.1.2 Master Node Pull-Up Reverse Blocking Diode

The maximum voltage drop in the Master node pull-up reverse blocking diode is 1.0 V at the maximum current; the current limited by the transceiver or 30 mA, whichever is smaller.

The minimum power dissipation of the diode is determined by the current through the diode. It shall be at least 20 mW if the transceiver limits the current to the load pin to a maximum of 20 mA; otherwise, it shall be 30 mW.

7.6.1.3 Master Node Capacitance

The Master node load capacitor shall be as specified in Table 6 and Figure 4 with voltage rating appropriate to a maximum loaded network under worst case environmental and electrical conditions.

7.6.1.4 Slave Node Capacitance

The Slave node load capacitor shall be as specified in Table 6 and Figure 3 with voltage rating appropriate to a maximum loaded network under worst case environmental and electrical conditions.

7.6.1.5 ESD Transient Suppressor

If necessary, a circuit element such as a transorb (back-to-back zener) or a varistor device may be added to the network in one or more places to provide ESD protection. However, when these devices are used they may add capacitance or introduce voltage and/or temperature variability to the network time constant. When such devices are used the device load capacitor shall be reduced by an amount equivalent to the capacitance of the ESD transient suppressor. See Figures 3 and 4.

7.6.2 BOARD LAYOUT REQUIREMENTS

1. All grounding of the LIN transceiver and the filter capacitors shall be made to ECU signal ground.
2. C1 and C_{LOAD} shall be monolythic ceramic chip capacitors. (Ceramic chip capacitors have low ESR and high self resonant frequencies.)
3. A ground plane is required under the transceiver chip on the same side of the board as the component.
4. Transceiver shall be located as close to edge connector as possible. Other IC's are not permitted between edge connector and the transceiver.
5. The LIN bus circuit between the edge connector and transceiver shall be as short as possible. Guard tracks are required for all LIN bus and Tx and Rx circuits.
6. All guard tracks shall be at least 0.5 mm wide and grounded at least every 10 mm. No signals shall be routed between the guard track and the LIN bus trace.

7.7 Network Topology

7.7.1 LOSS OF ECU GROUND

The loss of ground by any single slave ECU, with or without an accompanying loss of V_{batt}, shall not cause any bus voltage offset that will disable normal communications (See $I_{leak\ gnd}$ in Table 6).

7.7.2 LOSS OF ECU BATTERY

The loss of battery by any single slave ECU, with or without an accompanying loss of ground, shall not cause any bus voltage offset that will disable normal communications (See $I_{leak\ batt}$ in Table 6).

7.7.3 BUS ELECTRICAL LOAD DISTRIBUTION

Each Slave ECU shall contain a slave device capacitance load and a slave termination resistive load.

The total network equivalent minimum resistance (R_{tl}) and maximum capacitance (C_{tl}) shall comply with the totals specified in Table 6.

7.7.4 BUS WIRING TOPOLOGY CONFIGURATIONS

The data link physical medium wiring mechanization can be implemented in any of the following ways:

1. Vehicles may be wired in a ring, a star, or a combination of both. Note that ECU's that are intended for use across multiple platforms may have two connector pins as shown below to allow a ring connection.
2. The pins of the ECU when applied in a ring, shall be adjacent and in the same connector, shorted together as close to the connector as possible, and share EMC and/or loading components.
3. If in a star configuration, the ECU requires only one pin for LIN.

The topology of the LIN bus shall be determined for each vehicle platform based on the vehicle's fault tolerance, serviceability, and bus length requirements. A second bus wire connector terminal for the LIN circuit at each ECU allows for implementation of a ring configuration, although it is not required that both terminals be used. A ring, star, or combination of ring and star configuration is acceptable as long as all other LIN wiring requirements are met. Illustrations of the LIN topologies are shown in Figures 5, 6, 7, and 8 below.

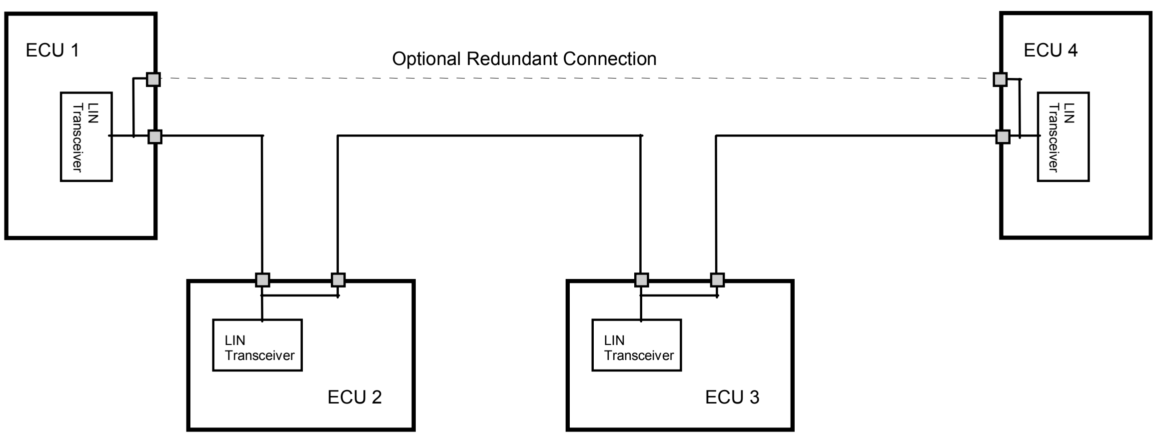

FIGURE 5—LIN RING TOPOLOGY

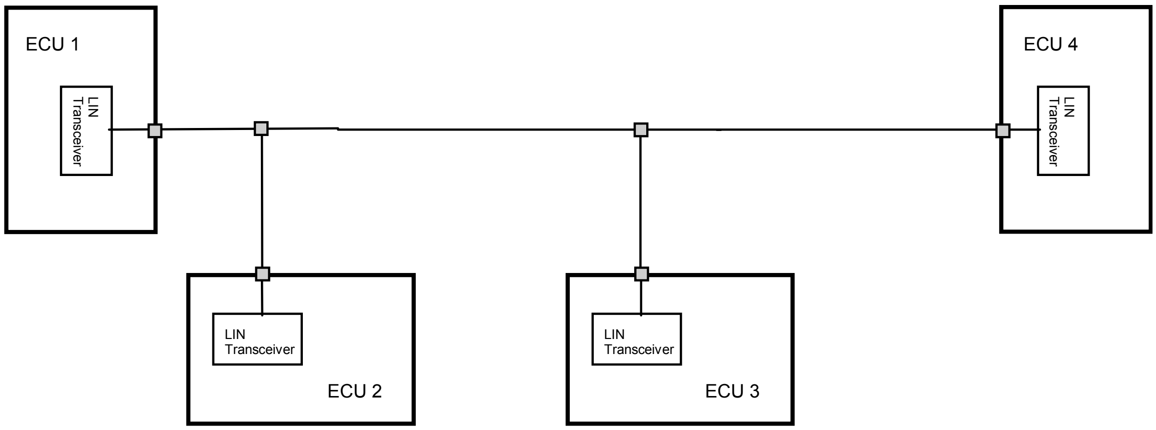

FIGURE 6—LIN LINEAR TOPOLOGY

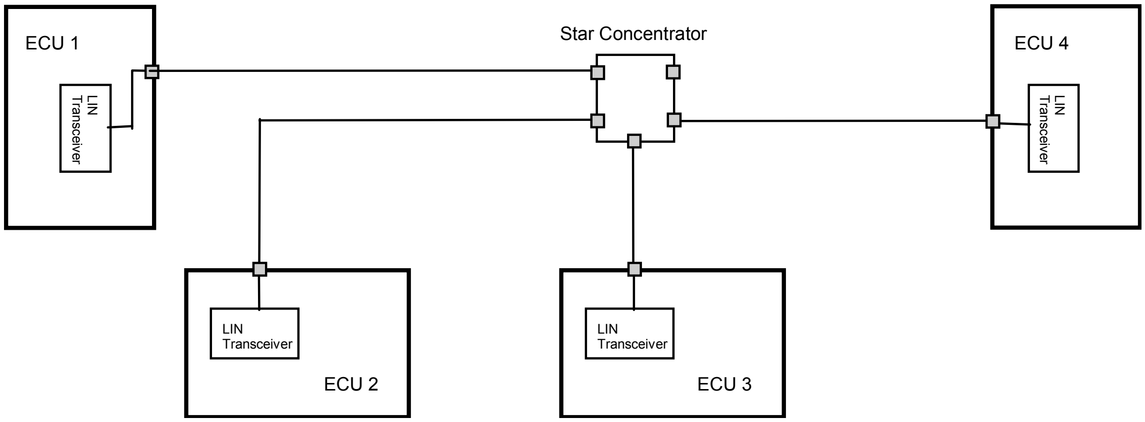

FIGURE 7—LIN STAR TOPOLOGY

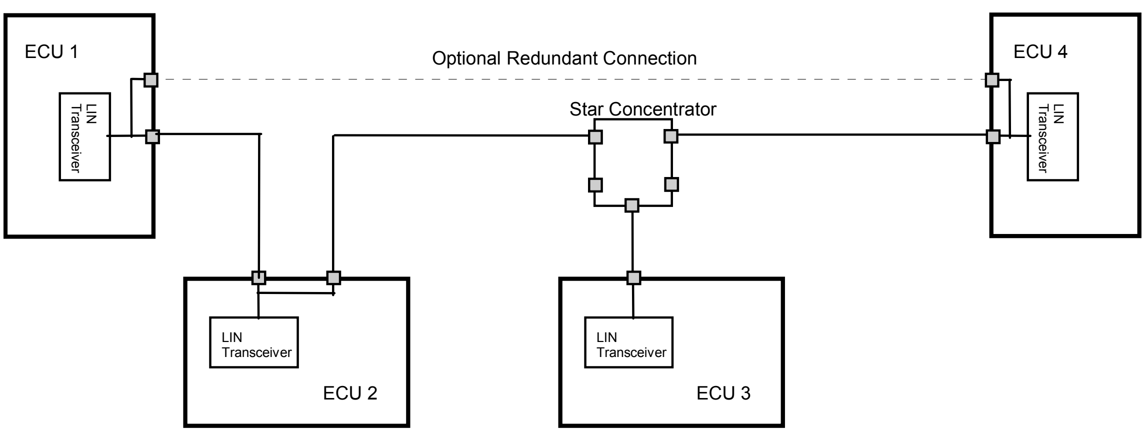

FIGURE 8—LIN COMBINATION RING AND STAR TOPOLOGY

7.7.5 BUS WIRING CONSTRAINTS

The vehicle network wiring and ECU system shall meet the following constraints:

1. The total bus wiring capacitance shall not cause the network time constant to be exceeded. (see Table 6). The maximum bus length allowed is determined by the number of nodes in the network system and their R-C characteristics.
2. There shall be no more than 40 meters between any two network system ECU nodes.

The following table uses the maximum network time constant to determine the maximum wire length that can be used to connect a given number of ECU's. This maximum wire length depends on the Master Node Capacitance and the number of slave nodes. In calculating these numbers it was assumed that all resistors are at the maximum allowed values and capacitors (10%) are at their maximum tolerance, that the capacitance of the wire was 100 pF/m, that the slaves all have nominal capacitances of 220 pF and that an additional 30 pF of capacitance are added due to PCB traces and Connectors.

Table 7 shows the maximum wire length allowed on the vehicle based on the number of nodes on the vehicle and their characteristics. The legend in Table 7 gives the capacitance in the Master Node.

The maximum vehicle wire length is calculated using the following equation:

$$Wire_l = [\tau_{Network} /(R_s \text{ / \# slave nodes } || R_m) - C_m - C_s * \text{ \# slave nodes}] \text{ / wire(C/m)} \qquad \text{(Eq. 1)}$$

TABLE 7—#NODES/NETWORK RESISTANCE/MASTER NODE CAPACITANCE VS. MAX WIRE LENGTH CHART

	$C_{master\ pF\ (max)}$		
# slave nodes	**272**	**778**	**2450**
1	40.85 m	35.79 m	19.07 m
2	38.96 m	33.90 m	17.18 m
3	37.07 m	32.01 m	15.29 m
4	35.19 m	30.13 m	13.41 m
5	33.30 m	28.24 m	11.52 m
6	31.41 m	26.35 m	9.63 m
7	29.53 m	24.47 m	7.75 m
8	27.64 m	22.58 m	5.86 m
9	25.75 m	20.69 m	3.97 m
10	23.87 m	18.81 m	2.09 m
11	21.98 m	16.92 m	0.20 m
12	20.09 m	15.03 m	0 m
13	18.21 m	13.15 m	0 m
14	16.32 m	11.26 m	0 m
15	14.43 m	9.37 m	0 m

7.7.6 BUS WIRING PRACTICES TO IMPROVE EMC PERFORMANCE

1. Avoid routing bus wire signals with noisy (e.g., injector drivers) and sensitive (e.g., low signal level sensors, antenna feeds) circuits.
2. Precaution shall be taken when routing signals near antennae or antenna amplifiers to prevent inducing noise into these circuits. A shielded wire may be needed near an active antenna.
3. Avoid wire loops by locating bus wires close to the vehicle's metal ground plane or route a ground wire with the bus wire.

7.7.7 BUS WIRING HARNESS AND ECU CONNECTORS

Connectors shall have less than 50 milliohms resistance over total vehicle life.

7.8 ESD Immunity

The ECU LIN Bus I/O pin shall withstand the following electrostatic discharges without any damage to the ECU when subjected to the Ford EMC Test – Electrostatic Discharge Immunity test (Section 19). The particular vehicle manufacturer's ECU component technical specification shall state the Criticality Level of the device. If the component technical specification does not specify the ESD level, use the requirements in Table 8.

TABLE 8—ESD IMMUNITY REQUIREMENTS

ECU Condition	Contact	Air (Non-Contact)
Unpowered	± 6 KV	±8 KV

7.9 EMC Testing Requirements

The LIN physical layer, when incorporated into an ECU design, shall function as specified in the ECU's intended electromagnetic environment. Additionally, the electromagnetic emissions produced during LIN related operations shall not interfere with the normal operation of other ECU's or subsystems.

Testing using the below listed Ford EMC series of tests shall be used to assess the EMC performance of a LIN physical layer design. Required testing methods include the following EMC test specifications.

1. Section 7.0 Radiated RF Emissions: RE310
2. Section 10.3 RF Immunity Requirements 1 – 400 MHz: RI112, level 1 unless otherwise specified in the component spec.
3. Section 10.4 RF Immunity Requirements 400 – 3100 MHz: RI114, level 1 unless otherwise specified in the component spec.

7.10 Fault Tolerant Modes

The Network shall meet the requirements as defined per the following failure modes:

1. ECU Power Loss - ECUs shall not interfere with normal communication among the remaining bus ECUs during a loss of power (or low voltage) condition. Upon return of power, normal operation shall resume without any operator intervention within a time determined by the vehicle manufacturer.

2. Bus Wiring Short to Ground - Network data communications may be interrupted but there shall be no damage to any ECU when the bus is shorted to ground. A network impedance of less than 50 ohms between the bus and ground shall be considered a short to ground and continued communications are not guaranteed or required. Upon removal of the fault, normal operation shall resume without any operator intervention within a time determined by the vehicle manufacturer.
3. Bus Wiring Short to Battery - Network data communications may be interrupted but there shall be no damage to any device when the bus is shorted to positive battery less than 26.5 volts (V_{batt} < 26.5 volts). A network impedance of less than 50 ohms between the bus and battery shall be considered a short and continued communications are not guaranteed or required. Upon removal of the fault, normal operation shall resume without any operator intervention within a time determined by the vehicle manufacturer.
4. A short or open in any single wiring circuit of an ECU, except for power, ground, or serial data, shall not preclude the ability to communicate with that ECU for diagnostic purposes.

7.11 Ground Offset Voltage

Ground offset voltage limits at the ECU as specified in Table 6 must be maintained over the entire range of 8 < $V_{batt\ ECU}$ < 26.5 volts.

7.12 Operating Battery Power Voltage Range

7.12.1 NORMAL BATTERY VOLTAGE POWER OPERATION

Unless otherwise specified by the Component Technical Specification, ECUs shall be capable of meeting all requirements specified in this document when the $V_{batt\ ECU}$ voltage as measured at the ECU power input pin is within the range of 8 to 18 volts DC. The ECU shall provide $V_{batt\ IC}$ to the bus transceiver within the range of 7 to 18 volts when $V_{batt\ ECU}$ is in the range of 8 to 18V.

7.12.2 BATTERY POWER OVER-VOLTAGE OPERATION

Communication in the 18< $V_{batt\ ECU}$ < 26.5 volt range is not guaranteed. If communication is required in this range the ECU must limit the voltage to the transceiver to 18 V. If the voltage to the transceiver is not limited to 18V, communication is not guaranteed with $V_{batt\ ECU}$ above 18V. If deterministic behavior of the network is desired in this range, the master shall determine the state of the bus, i.e. by forcing the bus to go to sleep, communicating with specific devices, etc..

1. For 18 < $V_{batt\ ECU}$ < 26.5 volts the bus may operate in either the normal or the passive mode. Nodes shall only enter the passive mode in this voltage range in order to protect themselves, they shall not shut down due to voltage alone. In the passive mode the bus shall be recessive (not be pulled or driven to ground) and RxD shall be in the high state.
2. Recessive state transceiver leakage current limits shall be maintained over this range.
3. ECU's shall not sustain permanent damage when subjected to $V_{batt\ ECU}$ up to 26.5 volts. (See Section 18 in the Ford EMC spec.)
4. $V_{batt\ ECU}$ transients of greater than 40 volts and/or duration greater than 10 milliseconds must be clamped to avoid damage to the transceiver.
5. The transceiver shall not transmit a dominant state on the bus when the TxD is in a recessive state.

7.12.3 LOW BATTERY VOLTAGE OPERATION

For $0 < V_{batt\ ECU} < 8.0$ volts the bus may operate in either the normal or the passive mode. In the passive mode the bus shall be recessive (not be pulled or driven to ground) and RxD shall be in the high state.

7.12.4 BATTERY OFFSET VOLTAGE

The battery offset voltage limits, between the battery input pins of any ECU, specified in Table 6 must be maintained over the entire range of $8.0 < V_{batt\ ECU} < 26.5$ volts.

7.12.5 REVERSE BATTERY BLOCKING DIODE

The reverse battery blocking diode voltage drop between the ECU's $V_{batt\ ECU}$ input pin and the transceiver's $V_{batt\ IC}$ input pin shall be $V_{diode} \leq 1.0$ volts.

7.13 Environmental Requirements

ECU environmental requirements shall be specified in the individual ECU Component Technical Specifications that call out this specification. In general, communications devices, which are installed in these ECUs, shall operate in the –40 °C to +125 °C temperature range.

7.13.1 TRANSMIT OPERATING CONDITIONS

7.13.1.1 Master Device

A master device shall be able to transmit continuously when 90% of the bits transmitted are dominant to accommodate transmitting $00 data consecutively.

7.13.1.2 Slave Device

A slave device shall be able to transmit continuously when it is transmitting a dominant for 70% of the message time.

7.13.1.2.1 Stand-Alone Transceivers

Stand-alone transceivers shall also be able to drive the bus dominant for 5 ms, the maximum wake-up pulse time.

7.13.1.2.2 Integrated Transceivers

Integrated transceivers shall be able to drive the bus dominant for the time requested by the application, no more than 5 ms.

8. Validation

ECU's shall be required to pass the network functional performance validation tests as specified by the vehicle manufacturer. Environmental and other requirements shall be specified by the vehicle manufacturer's component technical specification that references this document.

ECU suppliers shall validate that after the vehicle manufacturer's salt fog and biased humidity accelerated life tests, the resistance between LIN pin and V_{batt} pin shall be greater than 20 Kohms for Slave nodes and 900 ohms for Master nodes.

ECU suppliers shall validate that after the vehicle manufacturer's salt fog and biased humidity accelerated life tests, the resistance between LIN pin and Ground pin shall be greater than 500 Kohms.

9. Notes

9.1 Marginal Indicia

The change bar (l) located in the left margin is for the convenience of the user in locating areas where technical revisions have been made to the previous issue of the report. An (R) symbol to the left of the document title indicates a complete revision of the report.

PREPARED BY THE SAE J2602 LIN TASK FORCE OF THE
SAE VEHICLE ARCHITECTURE FOR DATA COMMUNICATION STANDARDS COMMITTEE

APPENDIX A
LIN DEVICE SUPPLIERS

The following is a list of known device suppliers as of the date of publication. Please visit the following websites for information on the available devices.

AMIS – www.amis.com
AMS – www.austriamicrosystems.com
Infineon – www.infineon.com
Melexis – www.melexis.com
Microchip – www.microchip.com
Motorola – www.motorola.com/semiconductors/lin
ON Semiconductor – www.onsemi.com
Philips – www.semiconductors.philips.com
Renesas – www.renesas.com/eng
STMicroelectronics – www.ST.com

APPENDIX B
SIGNAL ENCODING TYPES

B.1 ASCII (ASC)

ASCII data uses a one byte code to represent a text character. ASCII data is most often used where the consumer of the data is a display device which recognizes ASCII characters and can therefore display the data without further conversion. The least significant 7 bits represent the standard ASCII codes from 0 to 127. The most significant bit is reserved at this time but may be assigned a special function in the future. All ASCII signals shall have a length in bits which is a multiple of 8.

Example : The ASCII code for „A" is $41.

B.2 Boolean (BLN)

Boolean signals are used to encode data that contains binary parameters, such as status bits or flags. A Boolean signal is always a single bit and is always encoded with the values True (=1) and False (=0). Boolean signals are named such that the name implies the information being transferred when the value of the variable is True.

Examples: For a signal named Windshield Wiper Switch Active: $0 = False, $1 = True.

B.3 Enumerated (ENM)

Enumerated signals are used for data that can take one of several states such as Day of Week or Wiper Mode. Enumerated definitions contain a field for describing states within the signal. There are up to 2^n possible states where n is the number of bits reserved for the signal. The state definitions should be created such that all of the states are mutually exclusive. Note that all states do not need to be defined.

Example: A signal representing Day of the Week may be defined as a three bit scalar with the following decoding

b000 = Invalid Day of the Week
b001 = Sunday
b010 = Monday
b011 = Tuesday
b100 = Wednesday
b101 = Thursday
b110 = Friday
b111 = Saturday

B.4 Numeric Signals

The units preferred for numeric data type signals are SI units (meters, kph, degrees C, etc.). However, use of dimensionless quantites (% open, etc.) is also allowed.

A numeric signal must encode values which are continuous throughout the defined range of the signal. Use of specific numeric values to communicate state information is not allowed.

B.4.1 Binary Coded Decimal (BCD)

Binary Coded Decimal (BCD) encoding is used when it is desirable to report decimal data in a nibble, and is often used where the data consumer is a display device. A BCD encoded signal shall be 4 bits long. Valid BCD data are the hex characters 0-9 with the following encoding

$0 = 0 decimal
$1 = 1 decimal
$2 = 2 decimal
$3 = 3 decimal
$4 = 4 decimal
$5 = 5 decimal
$6 = 6 decimal
$7 = 7 decimal
$8 = 8 decimal
$9 = 9 decimal
$A - $F = invalid

For example, the hex byte $25 would be interpreted as 37 decimal. As two BCD characters, the value is interpreted as 25 decimal.

B.4.2 Signed Numeric (SNM)

Signed numeric (SNM) signals are represented in 2's complement notation. If the most significant bit of the number is set to one (1), then the number is interpreted to be negative. The absolute value of the number is found by taking the 2's complement of the number. (The 2's complement is found by inverting each bit of the number and then adding a binary one (1) to the result.) For example, the number $FF, which has its most significant bit set, corresponds to -1. Each signal definition contains a field for resolution per bit (R), data length in bits (L), minimum and maximum value, and units.

The maximum value of the signal is:

$$Max = R^{*}[2^{(L-1)}-1] \qquad \text{(Eq. B1)}$$

The minimum value of the signal is:

$$Min = -R^{*}[2^{(L-1)}] \qquad \text{(Eq. B2)}$$

B.4.3 Unsigned Numeric (UNM)

Unsigned numeric (UNM) encoding is used for signals which are continuous in range, such as temperature, speed, or percent. The signal may or may not have an offset. Unsigned numeric signals can also be used for sequential data such as month (1 - 12) or day of month (1 - 31). Each signal definition contains a field for resolution per bit (R), data length in bits (L), Offset , minimum and maximum value, and units. From these characteristics, the transfer function between computer units (N) in decimal, and engineering units (E) of the data may be derived as follows:

$$E=N^{*}R + Offset \qquad \text{(Eq. B3)}$$

The maximum value of the signal is:

$$Max = R^{*}(2^{L} -1) + Offset \qquad \text{(Eq. B4)}$$

The minimum value of the signal is:

$$Min = Offset \qquad \text{(Eq. B5)}$$

B.4.4 Signed Floating Point [Scientific Notation] (SFP)

Signed Floating Point (SFP) is used to encode signals requiring representation in floating point arithmetic, and always includes a leading sign character. The format exactly follows the ANSI/IEEE Standard (Std 754-1985) Single format. Please note that this signal type consumes 4 data bytes, where the data byte boundaries of the transmitted frame do not align with the boundaries of this format. The floating point signal is sent as a 32 bit (4 byte) variable. The bit order is shown below:

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

APPENDIX C
BIT TIMING CALCULATIONS

C.1 Relation Between Propagation Delay and Duty Cycle

Figure E1—Relation between propagation delay and duty cycle shows the relation between the transmitter propagation delay and the duty cycle. Both worst-case duty cycles can be calculated as follows:

$$D3 = \frac{T_{BIT} - t_{REC\,(MAX)} + t_{DOM\,(MIN)}}{2 \cdot T_{BIT}} \quad \text{(Eq. C1)}$$

$$D4 = \frac{T_{BIT} - t_{REC\,(MIN)} + t_{DOM\,(MAX)}}{2 \cdot T_{BIT}} \quad \text{(Eq. C2)}$$

It is important to notice that the timings of t_{REC} and t_{DOM} are a combination of both, transmitter propagation delay and slope time / slew rate.

The requirements for transmitter propagation delay can be derived out of the duty cycle equations C1 and C2:

$$t_{REC\,(MAX)} - t_{DOM\,(MIN)} \leq T_{BIT} - 2 \cdot T_{BIT} \cdot D3 = 15.9\mu s \text{ @ } 10.4 \text{ kBit/s \& } F_{TOL} = 2\% \quad \text{(Eq. C3)}$$

$$t_{DOM\,(MAX)} - t_{REC\,(MIN)} \leq 2 \cdot T_{BIT} \cdot D4 - T_{BIT} = 17.28\mu s \text{ @ } 10.4 \text{ kBit/s \& } F_{TOL} = 2\% \quad \text{(Eq. C4)}$$

It can be seen that the absolute transmitter propagation time is irrelevant. Only the difference between t_{REC} and t_{DOM} is relevant. As long as both equations C3 and C4 are fulfilled the LIN transmission is reliable.

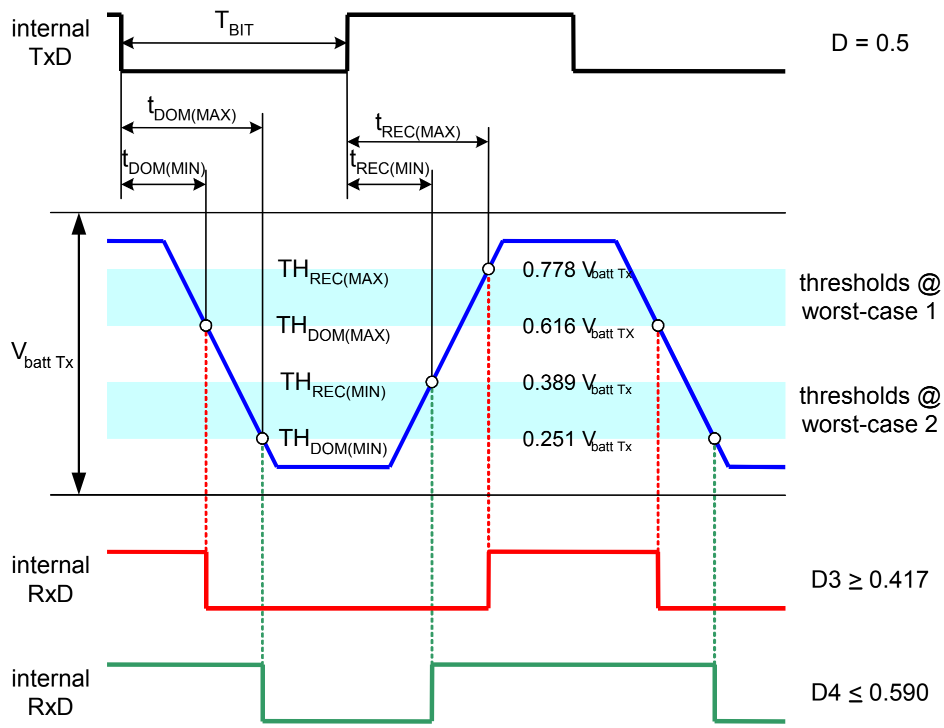

FIGURE C1—RELATION BETWEEN PROPAGATION DELAY AND DUTY CYCLE

NOTE—The threshold values shown are for the receiving node relative to the transmitting node's $V_{batt\ IC}$.

APPENDIX D
RATIONALES

D.1 Section 5.5

As defined in the LIN 2.0 Protocol Specification, TFrame_Maximum provides a “safety margin" of 40%. This represents an approximate 40% expense of bus bandwidth. This expense is not warranted when a slave device response can be guaranteed to be less than TResponse_Maximum.

D.2 Section 5.8.3

Data types other than scalar and byte array are expected to be utilized and exist within J2602 networks. The additional data types need to be correlated to the LIN-defined data types so that the data representations for slave devices can be consistently defined to insure interoperability and interchangeability.

D.3 Section 5.8.4

Clarification. The wording of Section 2.3 in the LIN 2.0 Protocol Specification can be interpreted that all unused or undefined bits in a frame of 8 bytes must be set to a recessive state and transmitted. In other words, this statement could imply that all messages must be 8 bytes in length.

D.4 Section 5.8.7

This status byte structure minimizes the number of bits needed to report the LIN Error states, while maximizing the number of bit available for the critical application status information. The LIN Error state hierarchy was chosen by the order the error could occur in the reception and transmission of frames on the LIN bus. There would be a low likely-hood of multiple LIN Errors occurring together, but if they do then they are reported in hierarchical order. When each error state is successfully reported in a Request Frame that state is automatically cleared by the Slave node. The choice of the state encodings also allowed support of the LIN 2.0 required Response_Error bit, without having to waste a separate bit in the status byte.

D.5 Section 5.9.2

As defined in Section 2.3.2 of the LIN 2.0 Protocol Specification, a slave node is not required to respond to an identifier to which they are defined as the publisher. If this situation occurs, the Master node cannot determine if the node has failed, or has no data to transmit. At least, one additional frame transmission is necessary to resolve the indeterminate condition.

Additionally, two slave nodes can potentially respond to a single identifier for which they both are defined as publisher. If they do, neither response can be interpreted by the Master node (because of the resulting destructive collision on the bus). At least, two additional frame transmissions are necessary to resolve the indeterminate condition and obtain the correct information from the slaves.

D.6 Section 5.9.3

Clarification of Section 2.3.3, LIN 2.0 Protocol Specification to state explicitly that the Master node is the one network entity that can initiate a frame of the Sporadic type.

D.7 Section 5.10.2.1

Section 5.1 of the LIN 2.0 Protocol Specification clearly defines the conditions allowing issuing of a Wake-up request up to and including the transmission of the fourth request. No definition or requirements are provided for continued generation of this request after the fourth request.

D.8 Section 7.5.3

Transmitting nodes shall not use double buffering because if an error occurs on transmission, no more bytes can be transmitted; however, the second buffered byte would start transmitting before the device could detect the transmission error of the previous byte.

APPENDIX E
BIT TIMING CALCULATIONS

E.1 Relation Between Propagation Delay and Duty Cycle

Figure E1—Relation between propagation delay and duty cycle shows the relation between the transmitter propagation delay and the duty cycle. Both worst-case duty cycles can be calculated as follows:

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$$D4 = \frac{T_{BIT} - t_{REC\ (MIN)} + t_{DOM\ (MAX)}}{2 \cdot T_{BIT}} \qquad \text{(Eq. E2)}$$

It is important to notice that the timings of t_{REC} and t_{DOM} are a combination of both, transmitter propagation delay and slope time / slew rate.

The requirements for transmitter propagation delay can be derived out of the duty cycle equations E1 and E2:

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$$t_{DOM\ (MAX)} - t_{REC\ (MIN)} \leq 2 \cdot T_{BIT} \cdot D4 - T_{BIT} = 17.28\mu s \text{ @ } 10.4\ kBit/s\ \&\ F_{TOL} = 2\% \qquad \text{(Eq. E4)}$$

It can be seen that the absolute transmitter propagation time is irrelevant. Only the difference between t_{REC} and t_{DOM} is relevant. As long as both equations E3 and E4 are fulfilled the LIN transmission is reliable.

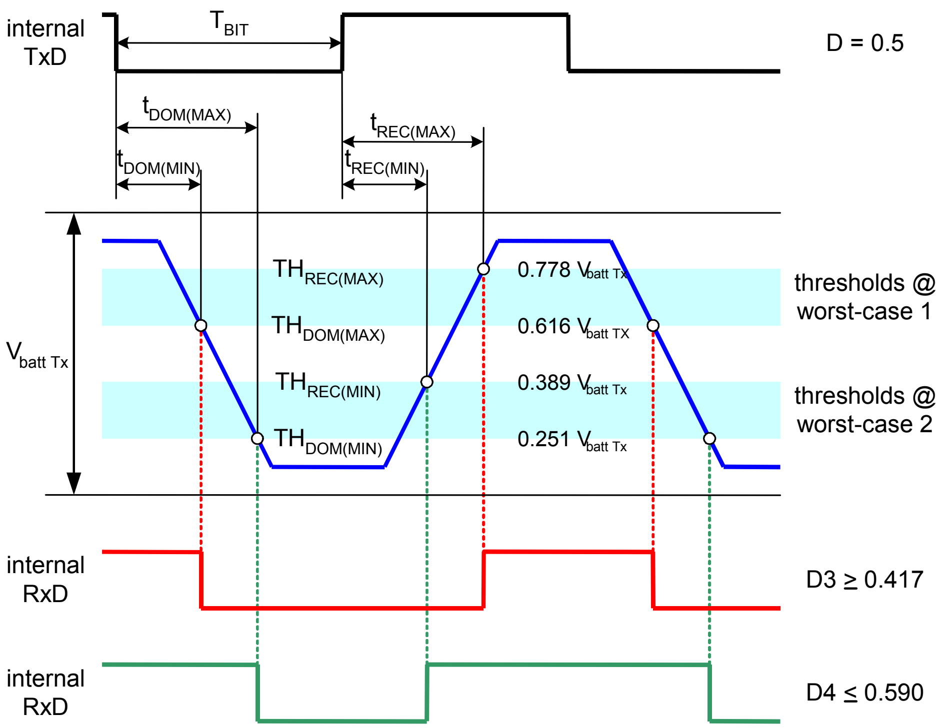

FIGURE E1—RELATION BETWEEN PROPAGATION DELAY AND DUTY CYCLE

NOTE—The threshold values shown are for the receiving node relative to the transmitting node's $V_{batt\ IC}$.