NATIONAL MARINE ELECTRONICS ASSOCIATION

NMEA 2000 ®

STANDARD FOR SERIAL-DATA NETWORKING OF MARINE ELECTRONIC DEVICES

Main Document

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Preface

NMEA Interface Standards are intended to serve the public interest by facilitating interconnection and interchangeability of equipment digital data, minimizing misunderstanding and confusion between manufacturer’s equipment, and being helpful to purchasers in their selection of equipment that should be compatible with each other.

This NMEA 2000 digital interface standard has been developed in conjunction with several well-known and familiar marine electronics manufacturers. Because of the nature of technology in today’s world it can be expected that this standard will be revised and updated on a regular basis. Therefore, one should always verify versions of this standard against any compatibility attempts.

The National Marine Electronics Association (NMEA) within this standard has been careful to provide a method or tool for various private enterprises to design equipment that should be able to share digitized data information with each other. However, NMEA accepts no responsibility for the actual implementation of this standard by each or any company who chooses to design to it.

Always when utilizing an electronic enhancement, including this digital interface standard, responsible parties need to apply common sense and be very careful to consider safety related concerns and thereby reassuring themselves that no inappropriate risk is being taken.

This standard has been developed in such a way to allow manufacturers the ability to insure mission critical data is transmitted timely and also that potentially faulty information can be exposed. However, it is the ultimate responsibility of each product manufacturer to insure design that takes advantage of this capability to aid them in safe exchange of data or information.

As an organization that is concerned with safe and enjoyable boating activities, NMEA continues to attempt bridging the gap between mutually exclusive activities that naturally exist in the world of products and people, and offer opportunities for improving equipment capabilities.

Updates of the Standard
This Standard may be modified from time-to-time by action of the NMEA Interface Standards Committee as the need arises.
1 General

1.1 Introduction
The need exists for standardized data communications between various electronic devices onboard vessels. Requirements cover the broad spectrum of simple data buses that distribute data, to full scale office/factory automation local-area-networks (LANs). NMEA 0183 (IEC 61162-1) provides serial-data distribution from a single transmitter to multiple receivers. NMEA 2000 is the marine industry open networking standard on all types of vessels. This standard was created and maintained by the NMEA 2000 Standard Committee and in collaboration with IEC TC80 and other expert groups like the United States Coast Guard. Several companies market various proprietary multi-transmitter network systems, often with NMEA 0183 input or output ports, but there is no compatibility between systems.

The International Electrotechnical Commission (IEC) provides standards to be referenced by the International Maritime Organization (IMO) for equipment required on board ships under the SOLAS convention. For distribution of digital data to equipment onboard ships IEC has adopted NMEA 0183 as the basis for IEC 61162-1, a single-transmitter/multi-receiver data bus. A higher speed variant of NMEA 0183/IEC 61162-1 is described by NMEA 0183-HS and IEC 61162-2. IEC has further identified the need for both moderate capacity instrument networks and high capacity LANs. IEC has adopted NMEA 2000 as the IEC 61162-3 standard.

The NMEA 2000 standard is referenced in the IEC 61162-3 and describes a low cost, moderate capacity, bi-directional multi-transmitter/multi-receiver instrument network to interconnect marine electronic devices on board ships under the SOLAS Convention.

1.2 Scope
This NMEA standard contains the minimum requirements for implementation of a serial-data communications network to interconnect marine electronic equipment onboard vessels. Equipment designed to this standard will have the ability to share data, including commands and status, with other certified equipment over a single signaling channel.

This standard is based on the Controller Area Network (CAN) and utilizes ISO 11783-3 and ISO 11783-5 as the foundation of the NMEA 2000 architecture. The NMEA 2000 Standard is similar to the Society of Automotive (SAE) standard J1939. The NMEA 2000 standard defines all of the pertinent layers of the International Standards Organization Open Systems Interconnect (ISO/OSI) model, from the Application Layer to the Physical Layer, necessary to implement the required NMEA 2000 network functionality.

Data messages are transmitted as a series of data frames, each with robust error checking, confirmed frame delivery and guaranteed latency times. As the actual data content of a data frame is typically 50% of the transmitted bits, this standard is primarily intended to support relatively brief data messages which may be periodic, transmitted as needed or on-demand by the
use of query commands. Typical data includes discrete parameters such as position latitude and
longitude, GPS status values, steering commands to autopilots, finite parameter lists such as
waypoints, and moderately sized blocks of data such as electronic chart database updates. This
standard is not necessarily intended to support high-bandwidth applications such as radar,
electronic chart or other video data, or other intensive database or file transfer applications. See
NMEA OneNet Standard (not yet published as of the date of this version) for these high
bandwidth applications.

The components of an NMEA 2000 network are:

- Physical Layer. Defined by this standard in § 2.0.
- Data Link Layer. Defined by ISO 11783-3 with additional requirements specified in this
document § 3.0.
- Network Layer. Defined by this standard in § 4.0.
- Network Management. Defined by ISO 11783-5 with additional requirements specified in
this document § 8.0.
- Application Layer. Defined by this standard in the NMEA Network Message Database
Appendix A which is now part of Appendix B (NMEA Network Message Database).

The scope and configuration of the NMEA 2000 network is illustrated Figure 1 -- NMEA 2000
Network, see also § 1.4 Definitions

The NMEA 2000 standard has been created to meet a wide variety of needs. One important
design requirement has been to provide for mission critical data and network operations. This
requirement is addressed through multiple levels of Parameter Group message priorities and
certification. Parameter Group message priorities are affected by Parameter group number
assignments, Device Class Codes, Device Function Codes, CAN message priority bits, and to
some degree, broadcast rates. Any device that a manufacturer desires to be NMEA 2000 certified
must adhere to the requirements within this standard, through automated software testing, and
validation (Appendix C – Certification Criteria and Test Methods). Any product that passes this
standard's certification tests will be capable of supporting mission critical network operations,
even if that product, in and of itself, is not related to the mission critical functions being
conducted on the NMEA 2000 network. Appendix D (Application Notes) describes how and to
what level safety and mission critical data and network operations are supported within NMEA
2000 networks.

This standard defines data formats, network protocol, and the minimum physical layer necessary
for devices to interface. Single point-of-failure conditions could exist that are capable of
disrupting network operation. For critical applications it may be necessary to employ fail-safe
designs (e.g., dual networks, redundant cables and network interface circuits) to reduce the
possibility of network failure. This standard provides support for the use of dual redundant
network systems for NMEA 2000 devices that are certified as Class 2 devices.
As of the publication of this version 2.000 of the NMEA 2000 Main Document, there are the following Appendices that comprise the entire edition of the NMEA 2000 Standard:

- NMEA 2000 Main Document
- Appendix A (Parameter Group Definitions) – Now Included with the purchase of NMEA Network Message Database.
- Appendix B (NMEA Network Message Database) (formerly known as PGN Definitions)
  - Appendix B-1 Parameter Groups (PGNs) (NMEA Network Messages)
  - Appendix B-2 Data Dictionary
  - Appendix B-3 Data Formats
  - Appendix B-4 Data Types
  - Appendix B-5 Reserved for Future use
  - Appendix B-6 Device Class & Function Codes
  - Appendix B-7 Alert Codes
- Appendix C (Certification Criteria and Test Methods)
- Appendix D (Application Notes)
- Appendix E -- ISO 11783-3 Data Link Layer
- Appendix F -- ISO 11783-5 Network Management
- Appendix G -- ISO 11898 Controller Area Network (CAN)
- Appendix H—Third Party Gateway Testing
- Appendix I – Cable & Connector Specifications & Requirements

### 1.3 Network Characteristics

#### 1.3.1 Network architecture:

- 254 network addresses (as per ISO 11783)(See § 1.3.3 for actual functional address space)
- Single channel
- Bus (parallel) wiring configuration
- Linear network with end terminations and multiple drops for individual nodes
- Network access: Carrier Sense/Multiple Access/Collision Arbitration
- Multi-master network operation, self-configuring.
- Special network tools, desirable for diagnostic purposes, are not necessary for operation.
1.3.2 Physical network size:
- Up to 50 physical node connections
- Signaling rate - backbone length @ 250kbits/second – 250 meters (using heavy or mid type cable, 100 meters using lite cable. For cable details see NMEA 2000 Appendix I). The maximum length of the network is controlled by the CAN requirement that all nodes on the network sample the same bit at the same time, the actual maximum length will be determined by the time delays on the network cable and in the interface circuits. Future versions of this standard may support additional signaling rates:
  - 1,000 kbits/second - 25 meters
  - 500 kbits/second - 75 meters
  - 125 kbits/second - 500 meters
  - 62.5 kbits/second - 1100 meters
- Drop length, maximum: 6 meters
- Node separation, minimum: 0
- Controller Area Network (CAN), Version 2.0B Extended Format

1.3.3 Functional network size:
- 252 network addresses, maximum

1.3.4 Media Access Control hardware:
- Controller Area Network (CAN), Version 2.0B Extended Format

1.3.5 Connectors, cables, terminations:
- Specified in Appendix I

1.3.6 Dedicated network power
- Specified in § 2.0 of this documentation
- Network interface operating range: 9 to 16 Volt DC
  - NOTE: Future operating ranges may be 9-32 Volt DC

1.3.7 Network fault operation is defined in Table 1-1:

<table>
<thead>
<tr>
<th>Condition</th>
<th>Network Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 A device is disconnected from the network</td>
<td>Possible temporary network interruption and/or re-initialization of network connected devices.</td>
</tr>
<tr>
<td>2 A device loses external power</td>
<td>No impact on network physical layer</td>
</tr>
<tr>
<td>3 A device loses external ground</td>
<td>No impact on network physical layer</td>
</tr>
<tr>
<td>4 A device loses network power</td>
<td>No impact on network physical layer</td>
</tr>
<tr>
<td>5 A device loses network ground</td>
<td>No impact on network physical layer</td>
</tr>
</tbody>
</table>
Figure 1 -- NMEA 2000 Network Connections
1.4 Definitions

Terms unique to this standard are defined below.

1.4.1 Appendix A – Parameter Group Definitions – NOW within the NMEA Network Message Database

1.4.2 bit. The smallest element of information on the communication channel. Bits are grouped into bit fields of one or more bits. A bit is of constant time duration set by the signaling rate specified in this standard and has one of two logical values, dominant or recessive. When dominant and recessive levels are impressed on the communications channel at the same time the resulting level is dominant.

1.4.3 bridge. A device that joins two network segments using the same network protocol and address space. Data rate and physical media may differ on the two sides of a bridge. A bridge may perform message filtering.

1.4.4 byte. Is made up of eight bits

1.4.5 CAN frame. A series of bits transmitted on the communications channel conveying the following types of information:

   - data frame. Carries data from a transmitter to the receivers.
   - error frame. Transmitted by a unit detecting a bus error.
   - overload frame. Transmitted to provide a delay between preceding and succeeding data frames.

   The CAN data frame has defined start of frame and end of frame bit fields and are separated from preceding fields by an interframe space. CAN error and overload frames, when used, are appended directly to the preceding frame without an interframe space.

1.4.6 default operation. The operation or settings that exist when standard equipment is first shipped from the manufacturer.

1.4.7 device. A Product or Equipment, which through a node is connected to a NMEA 2000 network. Can be logical devices where multiple addresses can be contained within a single node.

1.4.8 gateway. A device that joins a network to another network or system.

1.4.9 interframe space. A bit field that separates data frames from preceding frames.

1.4.10 may. The NMEA 2000 standard observes the following convention for the use of the word may relating to network requirements: Alternatives and optional items that are allowed in an NMEA 2000 network. An implementation that does not include an alternative shall be prepared to tolerate another implementation that does.

1.4.11 message. A message consists of one or more data frames, as specified in this standard, that contain the Parameter Group information to be communicated from a network address.
A message contains the message priority code, Parameter Group number, destination network address, source network address, and data fields. The destination network address may be a specific address or global.

1.4.12 network address. The location of a functional entity on the network.

1.4.13 network load, Is a unit of measure defined as 50mA. Is used to determine loading of the network. See 2.4.7.6.

1.4.14 network neutrality, Is the principle that all devices within a Class and Function Code are treated the same.

1.4.15 NMEA Network Message Database, This database contains all of the Parameter Group Numbers and Field definitions, formerly known as Appendix B.

1.4.16 node. The attachment of the physical layer implementation of a transmitter/receiver to the signaling channel. A node may represent more than one network address.

1.4.17 node power. Is the power supplied from the NMEA2000 Network

1.4.18 Parameter Group. A set of associated variables, commands, status, or other information to be transmitted on the network. Certain Parameter Groups, such as network management messages (e.g., Address Claim message), are defined in the Data Link Layer, §3.0, or Network Management, § 8.0, of this standard. Application related Parameter Groups (e.g., GPS data) are defined in the Application Layer section. See NMEA Network Message Database (Appendix A within the Network Message Database).

1.4.19 parameter group number. An 8-bit or 16-bit number that identifies each parameter group. The Parameter Group Number (PGN) is analogous to the three-character sentence formatter in the NMEA 0183 standard. By definition Parameter Groups identified by 16-bit Parameter Group Numbers are broadcast to all addresses on the network. Parameter Groups identified by 8-bit Parameter Group numbers may be used to direct data for use by a specific address. See § 3.0 Data Link Layer.

1.4.20 receiver. A receiver is the recipient of a message if the bus is not idle and the device is not a transmitter.

1.4.21 router. A device that joins two network segments with the same network protocol. On each side of a router address space, data rate and physical media may differ.

1.4.22 shall. The NMEA 2000 standard observes the following convention for the use of word shall relating to network requirements: Items that are required in an NMEA 2000 network.

1.4.23 shall not. The NMEA 2000 standard observes the following convention for the use of word shall not relating to network requirements: Items that are prohibited in an NMEA 2000 network.
1.4.24 *should.* The NMEA 2000 standard observes the following convention for the use of word *should* relating to network requirements: A recommendation that if followed could ease development or improve the operation of the network in some manner.

1.4.25 *transmitter.* A *transmitter* is the originator of a *message.* The unit remains a *transmitter* until it loses arbitration or until the bus becomes idle.

1.5 Normative References


1.5.2 Institute of Electrical and Electronic Engineers (IEEE): 754-1985 IEEE Standard for Binary Floating-Point Arithmetic. IEEE Standards, 445 Hoes Lane, PO Box 1331, Piscataway, NJ 08855-1331 USA


1.5.4 ISO-11898 - Road Vehicles - Interchange of Digital Information - Controller Area Network (CAN) for High-speed Communications. International Organization for Standardization, Case Postale 56, CH-1211 Genève 20, Switzerland. (Available from ANSI, 11 West 42nd Street, New York, NY 10036.)

1.5.5 "ISO/IEC 10646-1 (1993-05)". "The Unicode Standard, Version 2.0", ISBN 0-201-48345-9, Author: The Unicode Consortium, Publisher: Addison-Wesley. This is equivalent to the standard as to Unicode values and tables.

1.5.6 ISO 11783-3. Part 3 Data Link Layer - Tractors and Machinery for Agricultural and Forestry – Serial Control and Communications Data Network. International Organization for Standardization, Case Postale 56, CH-1211 Genève 20, Switzerland. (Available from ANSI, 11 West 42nd Street, New York, NY 10036.)

1.5.7 ISO 11783-5. Part 5 Network Management - Tractors and Machinery for Agricultural and Forestry – Serial Control and Communications Data Network. International Organization for Standardization, Case Postale 56, CH-1211 Genève 20, Switzerland. (Available from ANSI, 11 West 42nd Street, New York, NY 10036.)
1.5.8  ITU Recommendations. International Telecommunications Union, Place des Nations, CH-1211 Genève 20, Switzerland.

A. ITU-R M.493-7 Digital Selective-Calling System For Use In The Maritime Mobile Service.
C. ITU-R M.825-1, Characteristics of a Transponder System Using Digital Selective-Calling Techniques For Use With Vessel Traffic Services and Ship-To-Ship Identification
D. ITU-R M.1371 Technical Characteristics for a Universal Shipborne Automatic Identification System Using Time Division Multiple Access in the VHF Maritime Mobile Band


1.6 Informative References

1.6.1 American Practical Navigator, Defense Mapping Agency Hydrographic/Topographic Center, Publication No. 9, DMA Stock No. NVPUB9V1, Volumes I and II


1.6.3 IEC 61162-1: Digital Interfaces, Maritime Navigation and Radiocommunications Equipment and Systems, International Electrotechnical Commission, 3, rue de Varembe, CH-1211 Genève 20, Switzerland


2 NMEA 2000 Physical Layer

This section defines the electrical and mechanical aspects of the physical link between network connections, and specifies characteristics of the CAN devices and network interfaces to be used in NMEA 2000.

The electrical characteristics of the physical layer are dictated by the following network requirements:

- Dominant/recessive bit transmission.
- Differential signaling.
- Network single-point common signal reference.
- Bit rate and network length controlled time delays and network loading.

Differential signaling indicates powered interface circuits and a signal reference common to all nodes on the network. A single-point common reference is specified in order to avoid radio-interference caused by ground loops and to maintain control of ground-voltage levels between nodes such that they remain within the common-mode range (approximately +/-2.5 Volts) of the network transceiver circuits.

The single-point nature of the common signal reference may be achieved in a number of ways as illustrated in Figure 2 -- Network Common Signal Reference. Single-point power and common may be distributed via the network backbone cable or, for heavier current, by dedicated twisted-pair wires to individual devices. In all cases the power and common for the interface circuits does not connect to other power or ground in a network device. This isolation may be achieved by use of isolation circuits (e.g., optoisolators) within the device or by assuring that no power or ground connections, other than the network power and network common, connect to the device.

Figure 3-- Physical Layer Block Diagram illustrates a typical physical layer block diagram for a 4-wire (shield not shown) network with an isolated interface and a network power source.
common to all devices. Ground isolation, illustrated with optoisolators, is shown between the network and the connected device.
Figure 2 -- Network Common Signal Reference

NOTES:

DEVICE 1: TOTALLY ISOLATED FROM OTHER CIRCUITS, ALL DEVICE POWER FROM NETWORK SOURCE ON A DEDICATED CABLE

DEVICE 2: ISOLATION AT NETWORK INTERFACE, CONSUMES MINIMUM NETWORK POWER

DEVICE 3: ISOLATION AT SOME POINT WITHIN THE DEVICE PRIOR TO EXTERNAL I/O

DEVICE 4: TOTALLY ISOLATED, ALL DEVICE POWER FROM NETWORK CABLE

DEVICE 5: ISOLATION AT SOME POINT WITHIN THE DEVICE PRIOR TO I/O, POWER FROM NETWORK SOURCE ON A DEDICATED CABLE
2.1 General Requirements

2.1.1 Environmental

2.1.1.1 NMEA 2000 components and circuits should be designed to meet the Durability and Resistance to Environmental Conditions for “Exposed Equipment” of IEC 60945 (Third Edition) § 8. The requirements of § 8.8 (Rain) apply only to those network components actually intended to be exposed to rain and/or spray.

2.1.1.2 NMEA 2000 components and circuits should be designed to withstand extended storage (non-operating) over the temperature range of -40 to +85°C.

2.1.2 Radio Frequency Interference

2.1.2.1 NMEA 2000 components and circuits should be designed to meet the Unwanted Electromagnetic Emission requirements for “Exposed Equipment” of IEC 60945 (Third Edition) § 9.

2.1.2.2 NMEA 2000 components and circuits should be designed to meet the Immunity to Electromagnetic Environment conditions for “Exposed Equipment” of IEC 60945 (Third Edition) § 10.
2.2 Network Protocol Devices

2.2.1 Controller Area Network (CAN)

The NMEA 2000 serial communications protocol shall be implemented by integrated circuits (e.g., CAN controllers) meeting the requirements of ISO 11898 – Road Vehicles – Interchange of Digital Information - Controller Area Network (CAN) for High-speed Communication, using Extended Frames. This specification defines CAN using a 29-bit Identifier field and is included for reference in Appendix G of this standard.

2.3 Network Signaling Rate

The NMEA 2000 network signaling rate shall be 250K bits per second – 250 meters. Automatic bit-rate routines and methods of protecting the network from disruption due to mis-matched bit-rate are being developed and future versions of this standard may allow bit-rates higher or lower than 250K bits per second. These future rates are intended to support high performance, but shorter networks, or longer networks operating at slower speeds. For this reason it is recommended that hardware and software designs are capable of supporting the following rates:

- 1,000 kbits/second - 25 meters
- 500 kbits/second - 75 meters
- 125 kbits/second - 500 meters
- 62.5 kbits/second - 1100 meters

2.3.1 Bit Timing Parameters for 250K BPS

The bit timing parameters including bit rate, bit rate timing accuracy, sample point, sample mode, and the value of SJW establish requirements for each module to provide consistency across the network. While most of these parameters require programming of internal CAN controller registers, the timing accuracy is determined by the electronic components used to set the CAN controller oscillator frequency.

2.3.1.1 Bit Rate = 250K BPS (Bits Per Second)

2.3.1.2 Bit Rate Timing Accuracy = or better than 0.5% over temperature and life

2.3.1.3 Sample Point = Between 85% and 90%

2.3.1.4 Sample Mode = Single Sample (see Note 1)

2.3.1.5 SJW = As large as appropriate (see Note 2) = Tseg2 / Bit Period

---

Note 1
Although J1939 supports “2 of 3” sample mode, some CAN controllers (e.g. C167, etc.) do not support this feature. Because analysis does not exclude either sample mode and because NMEA wishes to allow the maximum number of controllers, the “single” sample mode is recommended.

Note 2
Larger values of SJW, which control resynchronization timing, maximize the ability of a CAN controller to adapt to the expected oscillator variance across all other CAN nodes. Depending on the main CAN oscillator frequency, selection of the SJW value is not trivial. Additional material may be found in Philips application note AN97046 “Determination of Bit Timing Parameters for SJA 1000 CAN Controller” by Egon Johnk & Klaus Dietmayer

2.4 Node Electrical Interface
The electrical circuits that interface the CAN controller to the network utilize differential signaling transceiver circuits to convert between network signal levels and CAN controller levels. Signals on the network are either dominant or recessive, functioning as Logic “AND”, with Logic “0” dominant over Logic “1”. DC power to operate the interface circuits is provided by the network (See § 2.4.7), and fault protection circuits within the interface are required to prevent damage from overvoltage and mis-wiring (See § 2.4.6).

The interface between a device and the network comprises the following four lines:
- NET-H, CAN “High” signal line
- NET-L, CAN “Low” signal line
- NET-S, power source positive
- NET-C, power source common

2.4.1 Shield Connections
It is required that shielded cables (See Appendix I) be used to facilitate meeting radio frequency interference requirements.

2.4.1.1 The shield shall not be electrically connected within the interface to the electronic device chassis or ground.

2.4.1.2 The shield shall be electrically continuous through the network connection.

2.4.1.3 The shield shall be connected to ground at a single point, normally the ship’s ground at the source of network power.
2.4.2 Isolation

2.4.2.1 DC Isolation
Node isolation is determined by measuring as illustrated. The minimum resistance between any terminal in the node’s NMEA 2000, 5-terminal interface circuit and to any other external electrical connection, such as a ground or voltage source, (i.e., ship’s battery) shall be greater than 100K Ohms. See Figure 4 -- Isolation Measurement.

2.4.2.2 AC Isolation
Node isolation is determined by measuring as illustrated. The maximum capacitance between any terminal in the node’s NMEA 2000, 5-terminal interface circuit and to any other external electrical connection, such as a ground or voltage source, (i.e., ship’s battery) shall not exceed a 100 pF capacitance measurement. See Figure 4 -- Isolation Measurement.
2.4.3 Network Signaling

The two signal lines carry differential signals with respect to the network power common. Signals on the network represent two states: Dominant state or Logic ‘0’, and Recessive state or Logic ‘1’. During the transmission of the Dominant state by one or more nodes the state of the network is Dominant.

2.4.3.1 The AC and DC voltage parameters of the network signals shall be as specified by ISO 11898 *Road Vehicles - Interchange of Digital Information, Controller Area Network (CAN) for High-speed Communication*. The nominal voltage levels are:

- **Dominant state:**
  - CAN+= 3.5V
  - CAN-= 1.5V
  - $V_{\text{diff}} = \text{CAN+} - \text{CAN-} = 2.0\text{V}$

- **Recessive state:**
  - CAN+= 2.5V
  - CAN-= 2.5V
  - $V_{\text{diff}} = \text{CAN+} - \text{CAN-} = 0.0\text{V}$

- **Common Mode range:**
  - Difference in network common voltage between nodes: -2.5 to +2.5 Volts

2.4.3.2 The interface shall be designed such that NET-H and NET-L signal lines are in the Recessive state, or at higher impedance levels, when node power is off.

2.4.4 Signal Time Delays

2.4.4.1 For proper arbitration and to ensure that CAN frames with the ACK bit properly set are sampled from the furthest device on the network, the following timing limit shall be maintained when the sample point is no less than 87% into the bit:

\[
(.87)T > 2(L*p_d + CAN_{IN} + CAN_{OUT} + TX + RX)
\]

Where:

- $T =$ Bit interval in nano-seconds
- $L =$ Length of the network in meters, including drop-lengths, between the two furthest nodes.
- $p_d =$ Propagation delay of the cable, ns/meter
- $CAN_{IN}, CAN_{OUT} =$ Internal delays of the CAN device, ns
- $TX, RX =$ Delays of the isolated transceiver circuits, ns

To meet the required network bit rate/length objectives of § 1.3:

2.4.4.2 The sum of the input timing delays of the physical layer shall not exceed 180 nano-seconds. The input timing delays include all circuit delays from the electronic device’s network connector through the CAN device to its bit timing logic unit (e.g., interface receiver delays, opto-isolation circuit delays, and CAN internal input delays).

2.4.4.3 The sum of the output timing delays of the physical layer shall not exceed 180 nano-seconds. The output timing delays include all circuit delays from the CAN device bit timing logic unit to the electronic device’s network connector (e.g., CAN internal output delays, opto-isolation circuit delays, and interface transmitter delays).
2.4.5 Interface Schematic Example

Figure 5 -- CAN Interface Circuit shows an example schematic diagram of the preferred interface circuit. This circuit illustrates the key points of an electrically isolated interface. The example shows the use of an ISO 11898 compliant transceiver integrated circuit (e.g., Philips PCA82C251, Unitrode UC5350) but other equivalent integrated or discrete circuit designs are possible. Isolation is shown between the CAN interface transceivers and the device circuits, including the CAN controller. High-speed optoisolators are illustrated that provide the interface between the NET-H and NET-L lines of the network and the TX0 and RX0 connections on the CAN controller. For the high-speed operation required in this interface the Slope control line in the example transceiver should be held at less than 1.0 Volt.

The illustrated transceiver circuit requires regulated +5 Volt power that is provided by the Regulator/Protective Circuits. The regulator may be a linear or switching type. The function of the protective circuits is to prevent damage to the regulator and the interface circuits from overvoltage and reverse voltage. It is important to note that it may be necessary to protect the transceiver circuit ground from high reverse voltage, the transceiver ground is indicated as a separate wire from network common (NET-C).

Not shown are details of the CAN controller connections, including CAN input bias requirements unique to the selected CAN Controller. Standard engineering practice for the design of high-speed digital circuits should be applied (e.g., power supply bypass filtering, and physical separation of the two ground systems).

Figure 5 -- CAN Interface Circuit
2.4.6 **Interface Protection**
In addition to meeting the electromagnetic immunity requirements of § 2.1.2 the interface circuits and the electronic device connected to the network are required to withstand overvoltage and wiring errors.

2.4.6.1 No permanent damage shall result from a voltage level of +/-18.0 Volts applied between any two wires in the interface for an indefinite period of time.

2.4.6.2 No permanent damage shall result from mis-wiring the interface lines in any combination for an indefinite time.

2.4.7 **Interface Power**
To minimize the complexity of the interface, while maintaining isolation from other device power and grounds, power for the operation of the interface circuits is provided by a network power source. To further minimize interface and wiring complexity, network power may be used, within the limits specified, to operate other circuits in the node in addition to the interface circuits. These additional circuits may include the CAN controller, microprocessors and peripherals, and other device loads.

As shown in Figure 2 -- Network Common Signal Reference various methods may be employed to isolate network power and common from other device power and ground connections. In some applications devices may take all operating power from the network power source, either from the backbone cable or a dedicated power cable, and achieve isolation by isolated packaging and mounting provisions (devices 1 and 4 in Figure 2). Other devices may take all, or the majority, of operating power from the network power source and provide simple isolation circuits at the input or output to other equipment such as actuators, etc. (devices 3 and 5 in Figure 2).

2.4.7.1 The interface shall operate over the range of 9.0 to 16.0 Volts DC. **Note:** Future voltage ranges may be 9 to 32 Volts DC.

2.4.7.2 Node power and common shall either be supplied from the network backbone cable and drop cable or supplied by a dedicated node power cable connected only between a single node and the network power/common (battery or one power supply).

2.4.7.2.1 When connected to the network backbone power source the node current shall not exceed 1.0 Amp including high-speed transients. If the node exceeds 1.0 Amps, then the device shall have its own dedicated power supply. (See § 2.4.7.2.2)

2.4.7.2.2 When a node is connected by a dedicated node power cable the connections for network power and common shall be physically separated and electrically isolated from other power and ground connections, if any, on the equipment.
2.4.7.2.3 When a node is connected by a dedicated node power cable the connections for network power and common shall be clearly labeled according to Table 2-1. The maximum peak node current for this configuration is not specified by this standard.

Table 2 Network Power Labeling

<table>
<thead>
<tr>
<th>Name</th>
<th>Label</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive</td>
<td>NET-S</td>
</tr>
<tr>
<td>Common</td>
<td>NET-C</td>
</tr>
</tbody>
</table>

2.4.7.3 The instantaneous peak value of the common voltage of all receivers with respect to any transmitter shall be within the common-mode voltage range of the ISO 11898 equivalent transceiver.

2.4.7.4 Node power and common shall not be electrically connected to other power or ground sources in the node. If a unit is to supply power to the NMEA 2000 Bus the supply must meet the specifications in § 2.5.1 Network Power Supply. This includes the requirement of isolation of the supply.

2.4.7.5 Node power and common currents should be carried in twisted pair wires and shall be balanced (i.e., the return current contains the same current components supplied by the node power source).

2.4.7.6 The manufacturer shall specify the power rating for each connected Node as a “load equivalency number” for use in planning network installations. One Network Load is defined as 50 mA or any portion thereof (e.g., a device taking 51 mA from the network power bus is a Two Network Load device).

2.4.7.7 Nodes connected to network power shall not introduce noise, ripple, or transients on the network power source in excess of levels allowed by § 9.2 Conducted Emissions of IEC 60945 (Third Edition).

2.4.7.7.1 For frequencies less than 10KHz conducted emissions shall be less than 0.25 Volts peak-to-peak.

2.4.8 Reaction to power disturbances

2.4.8.1 ECUs on the network shall be able manage voltage transients and interruptions, reacting according to the following.

2.4.8.2 If ECU_PWR is restored within 2 milliseconds and if interruptions are spaced at least 250 milliseconds apart, there shall be no

- Loss of normal network communications or in-process messages.
- Processor Reset
• Loss of data in volatile memory, such as network-configuration information or messages in progress over the network.

2.4.8.3 If power is disrupted for a period of time greater than 2 milliseconds the internal requirements of the ECU shall determine whether a reset is necessary.

2.5 Network Power Source

The power source shall be either a single-point connection to the vessel’s battery or one or more isolated power supplies distributed along the network, but not a combination of battery and power supply connections.

The maximum length of the network and the number of nodes that can be connected are constrained by limitations associated with data transmission and with DC power distribution. As the number of nodes with power requirements beyond that needed for an isolated interface increase, power distribution quickly becomes the limiting factor. For networks of shorter length and with a lower number of connected devices the ship’s battery may be used to power the network nodes directly. In place of the battery multiple electrically isolated regulated power supplies may be used if it is necessary to extend the size of the network.

The NMEA 0400 Installation Standard provides applications and information with suggestions for cable selection and the strategic location of a single battery connection or (multiple) power supply(s), and an installation worksheet.

2.5.1 Network Power Supply

2.5.1.1 DC Ground Isolation. Isolation is determined with the network power cables not connected, but all other power supply electrical connections made. The minimum resistance between the NET-S and NET-C terminals on the power supply and the power supply chassis, the ship’s ground, and the ship’s voltage source (i.e., ship’s battery) shall be greater than 100K Ohms.

2.5.1.2 Output voltage of the power supply shall be 15 Volts +/-5% over the full combined range of output load and input line variation.

2.5.1.3 Input line variation range for AC operated power supplies shall be +/-10% of the nominal AC Voltage value and +/-6% of the nominal 50 or 60 Hz line frequency.

2.5.1.4 Input line variation for DC operated power supplies shall be +30% to -20% of the nominal 12.0, 24.0 Volt, or other DC values.

2.5.1.5 The minimum output current capacity shall be specified by the manufacturer under the least favorable combination of input line value and output voltage and over the operating temperature range.
2.5.1.6 Output current surge capacity of 125% of the manufacturer’s specified capacity shall be provided for a duration of at least 1.0-second.

2.5.1.7 Output ripple shall be 0.25 Volts p-p (peak to peak) or less.

2.5.1.8 Output overvoltage protection shall be provided to limit the output voltage to 18.0V.

2.5.1.9 Output overcurrent protection shall be provided to limit current to 150% of the manufacturer’s specified capacity without requiring the replacement of fuses or resetting of circuit breakers.

2.5.1.10 The power supply shall operate with additional power supplies attached to the network and shall not sink current from power supplies with a higher output voltage.

2.5.1.11 The power supply shall have provision for attachment of the network shield to ship’s ground. In multiple power supply configurations the shield connection should be made at only one power supply (single-point ground).

2.5.1.12 If the Isolated Supply is provided by a node unit to power Network, the use of the supply shall be selectable.

2.5.1.13 Nodes connected to network power shall not introduce noise, ripple, or transients on the network power source in excess of levels allowed by § 9.2 Conducted Emissions of IEC 60945 (Third Edition).

2.5.1.13.1 For frequencies less than 10KHz conducted emissions shall be less than 0.25 Volts peak-to-peak.

2.6 NMEA 2000 Approved Network Cables & Connectors
See Appendix I for full NMEA 2000 Network Cable and connector requirements and test specifications.
3 NMEA 2000 Data Link Layer

The NMEA 2000 Data Link Layer is international standard ISO 11783-3 with additional provisions and requirements as described in this section. ISO 11783-3 is titled Tractors and Machinery for Agricultural and Forestry, Serial Control and Communications Data Network – Part 3 Data Link Layer and is included for reference in Appendix E of this standard.

1. When there are differences between the ISO 11783-3 specification and NMEA 2000, then NMEA 2000 shall be the guiding document.
2. ISO 11783-3 refers to vehicle, tractor, trailer, implements, machinery, forestry or agricultural equipment, etc. NMEA 2000 relates to boats and vessels.
3. When ISO 11783-3 refers to an ISO network this is construed to also include NMEA 2000 networks.

ISO 11783-3 is harmonized with the Society of Automotive Engineers SAE J1939-21 Recommended Practice for a Serial Control and Communications Vehicle Network – Part 21 – Data Link Layer.

3.1 Fast-Packet Messages

The fast-packet message mechanism is one of three methods of data transfer that is supported by this NMEA 2000 Standard. ISO 11783-3 provides for data transfer by two of these three methods:

1. Single-frame messages and
2. Multi-packet messages containing from 8 to 1785 data bytes.

Multi-packet message data transfers utilize the Data Transfer Transport Protocol (PGN 60160) Connection Management Transport Protocol (PGN 60416). Multi-packet protocols require the identity of the Parameter Group being transferred (PGN) be contained in the data fields (vs. CAN Identifier field), require flow control (Connection Management), and the insertion of a minimum inter-frame space of 50 ms for broadcast messages using PDU2 Format.

NMEA 2000, in addition to the two ISO 11783-3 message handling method described above, also provides and defines third method that we call a fast-packet message. The fast-packet message protocol is capable of transferring up to 223 bytes of data without use of a transport protocol and without a required inter-frame space beyond that specified in the CAN specification (ISO 11898). Fast-packet Parameter Groups are defined at the Parameter Group design stage and the PGN is contained in the Identifier field of each message in the same manner as a single-frame message.
3.1.1 Minimum Implementation of ISO Multi-Packet

NMEA 2000 implementation of ISO Multi-Packet does not require a device to be able to handle 1785 bytes of data. That is the upper bound of what is possible, not a requirement.

- Devices shall support ISO Transport Protocol Broadcast Announce Message (ISO TP.BAM) if the device requires the reception of any PGN capable of exceeding 223 bytes for their operation, except PGN 126208.

- Devices shall support ISO TP.BAM transmission if the device transmits any PGNs exceeding 223 bytes for their operation.

- Devices shall support ISO Transport Protocol Connection Management (ISO TP.CM) if the device requires the reception of any PGN capable of exceeding 223 bytes except PGN 126208 for their operation.

- Devices shall support ISO TP.CM transmission if the device transmits any PGNs exceeding 223 bytes for their operation.

3.1.2 Application of Data Transfer Methods

There are three methods (Single Frame, ISO Multi-Packet, NMEA Fast-Packet) of data transfer that are required for NMEA 2000 devices. As noted above, each of these methods have different characteristics, and offer different capabilities. The table below highlights some of the more significant issues with the Parameter Groups defined and supported by NMEA 2000.

<table>
<thead>
<tr>
<th>Single Frame</th>
<th>ISO 11783 Multi-Packet</th>
<th>NMEA 2000 Fast-Packet</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 bytes of data</td>
<td>Can convey up to 1,785 bytes of data</td>
<td>Limited to 223 bytes of data</td>
</tr>
<tr>
<td>Destination only as defined by PGN</td>
<td>Can be used to send any broadcast PGN (greater than 8 bytes) to a specific device</td>
<td>Destination only as defined by PGN</td>
</tr>
<tr>
<td>No handshaking</td>
<td>Contains “hand-shaking”, i.e. smart transfer methods</td>
<td>No handshaking</td>
</tr>
<tr>
<td>No Transfer Protocol Delays</td>
<td>Takes longer to send the same amount of data as Fast Packet</td>
<td>Takes less time to send up to 223 bytes. No Transfer Protocol Delays</td>
</tr>
<tr>
<td>Implemented by all industries</td>
<td>Implemented by all industries</td>
<td>New protocol</td>
</tr>
</tbody>
</table>
NMEA 2000 defines the data transfer methods for all NMEA 2000 supported Parameter Groups. The majority of these data transfer methods are Fast-Packet due to the size of the data.

Messages containing less than 9 bytes of data are defined using the Single Frame transfer method.

Messages defined to use the Fast-Packet data transfer method may also be sent or received via the Multi-Packet Transfer method, if the size of the data is greater than 8 bytes.

NMEA 2000 devices shall support all three data transfer methods.

3.1.3 Reply in Kind

NMEA devices may be used in NMEA 2000 networks, ISO 11783 networks, SAE J1939 networks, or other networks based upon ISO 11783. In order to facilitate proper network behavior, NMEA 2000 devices shall “Reply in Kind” in the following manner:

When a request or command requiring a response, is received using the Single Frame or Fast-Packet data transfer methods, the response shall use default data transfer method (Single Frame or Fast Packet).

- If ISO TP.BAM transmission is supported and a request or command requiring a response is received using the ISO TP.BAM, the response shall be provided using the ISO TP.BAM, unless the number of bytes in the response is less than 9. If the number of bytes in the response is less than 9, then the response shall be Single Frame, unless the default is Fast-Packet.

- If ISO TP.BAM transmission is not supported and a request or command requiring a response is received using the ISO TP.BAM, there shall be no response, unless the number of bytes in the response is less than 9. If the number of bytes in the response is less than 9, then the response shall be Single Frame, unless the default is Fast-Packet.

- If ISO TP.CM transmission is supported and a request or command requiring a response is received using the ISO TP.CM, the response shall be provided using the ISO TP.BAM, unless the number of bytes in the response is less than 9. If the number of bytes in the response is less than 9, then the response shall be Single Frame, unless the default is Fast-Packet.

- If ISO TP.CM transmission is not supported and a request or command requiring a response is received using the ISO TP.CM, the response shall be a TP.Abort, unless the number of bytes in the response is less than 9. If the number of bytes in the response is less than 9, then the response shall be Single Frame, unless the default is Fast-Packet.
When responding to an ISO Request, the responding unit shall not determine its response based on the requesting unit’s source address. In other words, if a unit would transmit the requested PGN to one of the units on the network, then the unit must transmit the requested PGN when requested by any of the units on the network.

3.1.4 Concurrent Message Processing

ISO 11783-3 defines the type of connections a node must support. NMEA 2000 adds the Fast-packet message to the type of connections and lists the number of connections that a node must support. NMEA 2000 devices shall at a minimum support the concurrent reception of the following messages:

- One single frame message
- Two fast-packet messages
- One multi-packet Broadcast message
- One multi-packet RTS/CTS session, if TP.CM reception is supported

3.1.5 Fast-packet Protocol

3.1.5.1 The first frame of a fast-packet message shall contain:

a) Identifier field according to ISO 11783-3:
   - Message priority, Reserved bit, and Data Page bit
   - Parameter Group Number identifying the PG being transmitted
   - Destination address if the message is directed to a single address, global otherwise
   - Source address of the sender

b) Data field:
   - Byte 1:
     - $b_0 - b_4 = 00000$, $b_0 = \text{LSB}$
     - $b_5 - b_7 = 3$-bit sequence counter to distinguish separate fast-packet messages of the same PGN, $b_5$ is the LSB of the counter.
   - Byte 2 = Total number of data bytes to be transmitted in the message (0 to 223). This number includes up to (6) data bytes in the first frame and up to (7) data bytes in following frames.

3.1.5.2 Additional frames, up to a maximum of 31, shall contain the following:

a) 29-bit Identifier field according to ISO11783-3:
   - Message priority, Reserved bit, and Data Page bit
   - Parameter Group Number identifying the PG being transmitted
   - Destination address if the message is directed to a single address, global otherwise
   - Source address of the sender
b) Data field:
- Byte 1:
  - $b_0 - b_4 = 1$ to 31, 5-bit frame counter
  - $b_5 - b_7 = 3$-bit sequence counter set to value in first frame.
- 7-bytes of transmitted data
- Unused bits in the last frame of a fast-packet message shall be filled with logic “1” bits.

3.1.6 Fast-packet Usage

3.1.6.1 Parameter Groups not defined as single-frame (see NMEA Network Message Database Appendix A) shall always be transmitted as either fast-packet according to this standard or by use of the multi-packet transport protocol according to ISO 11783-3.

3.1.6.2 Parameter Groups not defined as single frame shall not be transmitted without using the first two bytes of the first frame to indicate frame count, sequence counter, and message size even if the message size is 8-bytes or less.

3.1.6.3 The modulo 8 (Range 0 to 7) sequence counter shall increment each time the same PGN is transmitted from the same source address.

3.1.6.4 A separate sequence counter shall be utilized for each different PGN transmitted from the same source address.

3.1.6.5 Fast-packet messages of the same PGN may be transmitted at intervals of less than 100 Ms, see ISO 11783-3 Table 5.

3.1.6.6 Successive fast-packet frames may be transmitted without additional inter-frame delays.

3.1.6.7 This section made intentionally blank, previous requirement removed.

3.1.6.8 A fast-packet message shall not be considered as incomplete until a time-out of 750 ms from the last received frame occurs.

3.1.6.9 If not single-frame, when a Parameter Group designed as PDU2 format (using the Group Extension) is transmitted to a specific address, it shall be sent using the ISO 11783-3 Transport Protocol.

3.2 Request/Command/Acknowledgment Messages

ISO 11783-3 provides Request PGN 59904 for the purpose of requesting that a specific device (addressed) or all devices (global) transmit the Parameter Group specified in the data field of the PGN 59904 Request message. No additional request instructions are provided.
The normal reply to a request message is the data requested. ISO 11783-3 provides the Request Acknowledgment parameter group (PGN 59392) for use when required by the Application Layer (e.g., in response to a command message) or when the data requested by PGN 59904 is not sent. This acknowledgment message provides only minimum information when the result is a NACK and provides for only a single Group Function field.

NMEA 2000 additionally requires the use of the Request-Command-Acknowledgment parameter group (PGN 126208) defined in NMEA Network Message Database. This is a Group Function parameter group that utilizes the first data field of the message to indicate the function of the message. Three mandatory functions (a-c below) and four optional functions (d-g below) are provided:

a) Complex Request message, for requesting data, setting transmission timing, and for specifying variables in the request message,
b) Command message to set variables or initiate processes in a device, and
c) Acknowledgment message to confirm actions or to indicate reasons that a request or command message cannot be complied with.
d) Read Fields message provides a means to read specific fields in a PGN
e) Read Fields Reply message is a required response to the Read Fields message.
f) Write Fields message provides a means to write specific fields in a PGN.
g) Write Fields Reply message is the required response to the Write Fields message.

3.2.1 Complex Data Request Group Function Message

Complex Data Request Group Function (PGN 126208) is a fast-packet message requesting that a specifically addressed device, or all devices (global), transmit the requested Parameter Group repeatedly at a specified interval and a specified offset time. In addition the Complex Data Request is capable of specifying variables associated with the data being requested (e.g., the location of a stored waypoint may be requested by the field containing the waypoint name).

The use of the Complex Request message will vary from application to application. For example if a device had been requested to transmit GPS position fix data at a certain interval and another device requests a different interval the rate would be changed. On the other hand if a tracking radar had been requested to transmit Target No. 37 range and bearing at a three-second interval and a new request is received to send Target No. 43 at a four-second interval then both targets would be transmitted at three and four second intervals respectively.

The Complex Request Group Function message contains:

- Group Function code set to 0x00 indicating this message is a Complex Data Request.
- PGN of the requested information.
- Requested transmission interval
- Requested offset of transmission from time of request
- Number of request parameter pairs in following fields.
• Multiple pairs of fields specifying the field number and the parameter value for Parameter Groups that have selectable parameters. The field numbers and types of parameter values in the Complex Data Request message match the allowed request parameter fields in the requested Parameter Group. The fields requested may occur in any order in the message.

3.2.1.1 Support for the Complex Request Group Function message shall be implemented based on device certification level, in accordance with the minimum message implementation defined in § 9.0.

3.2.1.2 The Complex Request Group Function message shall be implemented as described in the NMEA Network Message Database – PGN 126208.

3.2.1.3 Compliance with the request (i.e., to send the requested data, and set transmission intervals and offsets) is optional.

3.2.1.4 All devices shall be capable of acknowledging a Complex Request message addressed to it. The acknowledgment is the data requested or the Acknowledgment message containing the appropriate error codes.

3.2.1.5 When a device provides mandatory or optional query support for a PGN containing “yes” for the Request Parameter fields (See NMEA Network Message Database - Appendix A § A-2.) it shall at a minimum support requests specified by those fields.

3.2.1.6 ISO 11783-3 Request message (PGN 59904) may be used when requesting a single data transmission without altering transmission-timing variables. However, the ISO Request message does not provide any way to specify “Request Parameters” (See NMEA Network Message Database - Note 4 in Appendix A-1). When requesting PGNs defined with required or optional “Request Parameters”, the response will depend upon the specific PGN being requested, but in general will evoke all possible responses of the given PGN. Refer to the description of the specific PGN being requested for the exact nature of the response.

3.2.1.7 NMEA 2000 devices shall support a Global Complex Data Request message requesting the Address Claim PGN 60928 and reply with the Address Claim parameter group when the Parameter Request fields contain no information (null) or when the contents of these fields match those of the device for any of the following fields (see Device Information § 8.3)

- Industry Group
- Device Class field
- System Instance field
- Function field
- Device Instance (upper) field
- Device Instance (lower) field
- Manufacturer’s Code field
3.2.2 Command Group Function Message

The NMEA 2000 Command Group Function message (PGN 126208) may be used to set variables within a device or to command changes of state. The Command Message accommodates multiple variables simultaneously and utilizes flexible command fields matching the format of the variable fields of the Parameter Group containing the variables being controlled. All parameter value fields are required to be padded if necessary to insure adherence to byte boundaries.

The Command Group Function message contains:

- Group Function code set to 0x01 indicating this message is a Command message.
- PGN of the message containing the fields being commanded.
- Number of commanded parameter pairs in following fields.
- Multiple pairs of fields specifying the field number and the parameter value for Parameter Groups that have commandable parameters. The field numbers and types of parameter values in the Command message match the allowed request parameter fields in the requested Parameter Group. The fields commanded may occur in any order in the message.

3.2.2.1 All NMEA 2000 devices may optionally support commands contained in the Command Group Function message.

3.2.2.2 The Command Group Function message shall be implemented as described in NMEA Network Message Database - Appendix A (§ A-1, #5).

3.2.2.3 This message shall only be addressed to a specific address.

3.2.2.4 The Acknowledgment Group Function message shall be transmitted in response to each Command Message indicating acknowledgment or containing the appropriate error code.

3.2.2.5 The ISO Acknowledge PGN shall never be the expected response to a Command PGN

3.2.3 Acknowledgment Group Function Message

The Acknowledgment Group Function parameter group (PGN 126208) is a fast-packet message sent to the specific address that originally issued a request or command.

The Acknowledgment reply supports more than one request parameter per message and provides information regarding the inability to comply with a request or command:

- PGN not supported
- Access denied. PGN, timing, and parameters otherwise supported
- PGN temporarily not available
- Transmit interval not supported
- Transmit interval is less than measurement/calculation interval
- Invalid request or command parameter field
- Unable to comply
• Request or command parameter out-of-range
• Request or Command Group Function not supported
• Access denied

The Acknowledgment Group Function message contains some of the following:

• Group Function code set to 0x02 indicating this message is the Acknowledgment message.
• PGN error code.
• PGN of Message being acknowledged
• Sequence Number (of the fast-packet request.command)
• Transmission interval error code.
• Variable number fields providing error codes relating to request or commanded parameters.

3.2.3.1 All NMEA 2000 devices shall support the Acknowledgment Group Function message.

3.2.3.2 The Acknowledgment Group Function message shall be implemented as described in NMEA Network Message Database, PGN 126208

3.2.3.3 The Acknowledgment message shall not be used in response to Global requests.

3.2.3.4 An Acknowledgment message, when required, shall be transmitted within 1 second of receiving the request or command.

3.3 ISO 11783-3 Requirements
Table 3-1 summarizes what are recommendations (e.g., “recommended”, “should”, and “may” terminology) in ISO 11783-3 in the sections identified below that are mandatory requirements of NMEA 2000. The terminology “will/will-not and must/must-not” used in ISO 11783 in the sections identified in the table below is considered equivalent to the terminology “shall/shall not” used in NMEA 2000.

This table is provided for clarification of terms that are either different between ISO 11783-3 and NMEA 2000, or to highlight a different emphasis between the standards. In instances where a description within this NMEA 2000 Standard is at variance with ISO 11783-3, a device manufacturer shall follow NMEA 2000.
Table 4 ISO 11783-3:1998(E) Requirements

<table>
<thead>
<tr>
<th>ISO 11783-3:1998(E) Sections</th>
<th>NMEA 2000 MANDATORY Interpretation / Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.2.2 Reserved Bit</td>
<td>All messages <em>shall</em> set the reserved bit in the CAN ID field to zero on transmit.</td>
</tr>
<tr>
<td>3.10.3 Transport Protocol, Connection Management PGN 60416</td>
<td>Data field Reserve Bits or Reserve Byte(s) <em>shall</em> be filled with ones. i.e. a reserve byte will be set to a hex value of FF, a single reserve bit would be set to a value of 1.</td>
</tr>
<tr>
<td>3.10.4 Transport Protocol, Data Transfer PGN 60160</td>
<td>Data field extra bytes <em>shall</em> be filled with a hex value of FF.</td>
</tr>
<tr>
<td>Annex C – Communication Mode examples, ACK or NACK requirement</td>
<td>If the PGN in a Command or Request is not recognized by the destination it <em>shall</em> reply with the ACK or NACK message.</td>
</tr>
</tbody>
</table>

3.4 Proprietary Messages

Proprietary messages provide a means for manufacturers to use the parameter group structure and definitions of this standard to transfer data which is beyond the scope of approved NMEA Network Parameter Groups.

These are the only conditions for the use of proprietary messages:

- **Condition 1**: The message is device specific such as, unique calibration or special configuration.
- **Condition 2**: Data is being used for test purposes.
- **Condition 3**: Data PGN is not available in the current NMEA Network Message Database.

In the case of condition 3, proprietary PGNs shall only be used until the necessary data fields are supported by a NMEA published Network Message.

The NMEA 2000 standard strongly encourages manufacturers to calibrate and configure their respective devices over the network. If manufacturers calibrate or configure their device over the network, they shall use PGN 126208.

NMEA encourages manufacturers to publish their proprietary PGNs, PGNs field descriptions and PGNs transmission rates.
3.4.1 Proprietary Format

Different Parameter Group Numbers are used in order to distinguish between single-frame and fast-packet or ISO multi-packet proprietary messages.

NMEA Network Message Proprietary PGNs are required to contain a Definer TAG (see § 3.4.3). The three fields in the Definer Tag are necessary so that the format and structure of a proprietary PGN may be known. Every PGN contains the source or sender’s address. This alone is not always sufficient in identifying the contents of a proprietary PGN.

3.4.1.1 Single-Frame Proprietary
PGNs 061184 (Destination Addressable) and 065280 through 065535 (Destination Global) are reserved for single-frame proprietary usage only.

These PGNs shall not be used for multi-frame messages, and cannot utilize the ISO 11783 multi-packet or NMEA Network Message fast-packet protocols.

3.4.1.2 Fast-Packet Proprietary
PGNs 126720 (Destination Addressable) and 130816 through 131071 (Destination Global) are reserved for non-single-frame proprietary usage only.

These PGNs shall be sent using the ISO multi-packet or NMEA Network Message fast-packet protocols.

Different Parameter Group Numbers are used in order to distinguish between single-frame and fast-packet or ISO multi-packet proprietary messages. By definition, those proprietary PGNs that are single frame shall have a higher priority than page 1 (see ISO 11783-3 Appendix E).

3.4.2 Proprietary Message Certification

Data that is defined within standardized NMEA Network Messages shall be conveyed using the standardized messages. For the benefit of the maritime community as a whole, the NMEA strongly encourages and supports all manufacturers to propose the standardization of their respective proprietary messages.

All proprietary messages shall be disclosed to NMEA for certification purposes. NMEA will not disclose this information. Manufacturers shall disclose the following confidential information:

- PGN number
- PGN title and or purpose
- PGN priority
- PGN update rate
- PGN acknowledgement requirements
- PGN data field descriptions
3.4.3 Definer Tag

A Definer Tag is a 16-bit entity, composed of 3 fields:

- the Manufacturer Code
- the Reserved 2-bit field
- the Industry Group.

See NMEA Network Message Database, Appendix A, Figure A-3 for an illustration of the Definer tag. NMEA 2000 proprietary PGNs are required to contain a Definer Tag in the first 2 data bytes of each message. The Definer Tag is necessary so that the format and structure of a proprietary PGN may be known. Every PGN contains the source or sender’s address. This alone is not always sufficient in identifying the contents of a proprietary PGN.

For example: Device 1 may wish to have device 2 send a proprietary PGN of device 1’s design. The source address indicates that this proprietary PGN is originating from device 2. The Definer Tag indicates that this proprietary PGN from device 2 adheres to a proprietary format defined by device 1. Additional identification fields may be necessary, depending upon how a manufacturer implements proprietary PGN formats.

3.5 Class 1 Devices

The term “Class 1” refers to devices that have a single network interface connection.

3.6 Class 2 Devices

The term “Class 2” describes devices that have two network interface connections. Class 2 devices are intended for use on dual redundant bus systems. Class 2 devices provide a means to identify messages that are received from redundant buses as being the same or different. This is accomplished through the setting and interpretation of the Data Length Code (DLC) value that resides in the header portion of every CAN frame in accordance with the ISO 11898-1 Data Link Layer. The use and application of the DLC field for Class 2 devices are contained here. (See § 3.6.1)

3.6.1 Class 2 DLC Usage

Application of the DLC as specified by the ISO 11898-1 CAN Data Link Layer Standard provides sufficient flexibility for additional interpretations of the DLC field. DLC values above the value of 8 are interpreted as a value of 8 by the CAN Data Link Layer, allowing this standard to use the values from 9 through 15 for the purposes of redundant message identification. Class 2 devices may be mixed with Class 1 (single interface) devices on the same bus because Class 1 devices do not interpret the DLC value above 8 to have any other meaning than the value 8.
Class 2 devices always, with two exceptions below (See §3.6.4.5 & §3.6.4.6), provide DLC values in the range of 9 through 15, making Class identification possible by examining the value of DLC field.

3.6.2 Class 2 NAME Entities
A Class 2 device shall have a unique NAME entity for each bus connection. The System Instance of the NAME entity shall be the only difference between the two NAME entities. The System Instance field of the NAME entities shall contain a default value of 0 for one bus connection and a default value of 1 for the second bus connection.

3.6.3 Class 2 Address Claim
Class 2 devices shall resolve to the same network address on both buses through synchronized execution of the address claim process.

3.6.4 Class 2 Transmissions
3.6.4.1 The power up default data transmit operation is that all data Parameter Groups are transmitted on both buses.
3.6.4.2 For each parameter group message that is transmitted on both buses, its (DLC field) identifier shall be the same for both bus transmissions.
3.6.4.3 If the parameter group message is packaged using the fast packet method, every packet of the transmission will bear the same identifier.
3.6.4.4 For every PGN transmitted by a Class 2 device, the DLC field shall contain a value between 9 and 15, and shall be incremented each time a new PGN is transmitted. The value shall restart at 9 once the value 15 has been used. The only exceptions to this are stated in § 3.6.4.5 and 3.6.4.6.
3.6.4.5 The DLC field of the ISO Request PG will not be modified.
3.6.4.6 The DLC field of the ABORT, CTS, and EOF frames of the ISO Transport Protocol will not be modified. The DLC identifier of the RTS and associated DT packets of a message transmitted on both buses using the ISO Transport Protocol shall be the same.
3.6.4.7 The DLC identifier of the BAM and associated DT packets of a message transmitted on both buses using the ISO Transport Protocol shall be the same.

3.6.5 Class 2 Reception
3.6.5.2 Reception of NMEA group function Requests and Commands on any bus will result in responses (data or NMEA group function Acknowledge) on both buses.
3.6.5.3 Reception of ISO Requests and ISO Commands on any bus will result in responses (data or ISO Acknowledgment) to be transmitted on both buses.
3.7 Redundancy
NMEA 2000 specifies two types of devices, those with one interface (Class 1) and those with two interfaces (Class 2). Redundancy may be achieved with two buses, with functions duplicated on each bus, thus providing function and bus redundancy at the system level.

Duplication of function on a single bus provides function redundancy at bus level only. System redundancy requires two buses. Function redundancy may be met by having multiple Class1 devices on each bus or Class 2 devices on both buses. Function redundancy can also be achieved with a combination of Class 1 and Class 2 devices across redundant buses.

See Appendix D for redundant implementation guidance.

4 OSI Network Layer Requirements
Defines how data is routed through a network from source to destination and may find utility if bridges, routers, or gateways are utilized to connect network segments or systems, or if multiple paths are provided. The deterministic characteristic of CAN may be degraded in network segment communications using router devices and real-time control applications between network segments may not be supported.

5 OSI Transport Layer Requirements
Not presently applicable to this standard. The minimum necessary elements of this layer are provided by the Application layer or Logical Link Control sub-layer.

6 OSI Session Layer Requirements
Not presently applicable to this standard. The Application layer or Logical Link Control sub-layer provides the minimum necessary elements of this layer.

7 OSI Presentation Layer Requirements
Not defined by this standard. The minimum necessary elements of this layer are provided by the Application layer or Logical Link Control sub-layer.

8 Network

8.1 Management
The specification for NMEA 2000 Network Management is international standard ISO 11783-5 with additional provisions and requirements as described in this section. ISO 11783-5 is titled Tractors and Machinery for Agricultural and Forestry, Serial Control and Communications Data Network – Part 5 Network Management and is included for reference in Appendix F of this standard.
8.1.1
When there are differences between the ISO 11783-5 specification and NMEA 2000, then NMEA 2000 shall be the guiding document.

8.1.2
When ISO 11783-5 refers to vehicle, tractor, trailer, implements, machinery, forestry or agricultural equipment, etc. NMEA 2000 relates to boats and vessels.

8.1.3
When ISO 11783-5 refers to an ISO network this is construed to also include NMEA 2000 networks.

ISO 11783-5 is harmonized with the Society of Automotive Engineers SAE J1939-81 Recommended Practice for a Serial Control and Communications Vehicle Network – Part 81 – Network Management.

8.2 Address Configurability

ISO 11783-5 allows four categories of address configurability: non-configurable, service configurable, command configurable, and self-configurable. See § 3.6 for the definition of Class 2 devices and additional address configuration requirements specific to Class 2 devices.

8.2.1 Self-configurable Addressing

NMEA 2000 devices shall be capable of self-configurable addressing. There are 252 claimable addresses within the address space defined by the set 0 through 251 inclusively (See Appendix D, § 3, NMEA 2000 Address Claim Procedures).

8.2.2 Non-configurable Devices

Non-configurable devices shall not be used on NMEA 2000 networks.

8.2.3 Commanded Address

NMEA 2000 devices shall accept a commanded address from a System Tool (See NMEA Network Message Database § B.6 – NMEA Class and Function Code Definitions).

Note:
Self-configuring addressing procedures are described in ISO 11783-5 (Appendix F) and NMEA 2000 Appendix D. This allows a device’s address to be claimed by another device with a NAME field of higher priority. Designers of network applications involving real-time control should be aware of the potential impact on real-time control during address re-assignment procedures.
8.2.4 Class and Function Codes

All NMEA 2000 devices shall have a unique Class and Function Code. The NMEA 2000 Standards has defined the Class and Function Codes in the NMEA Network Message Database (See NMEA Network Message Database § B.6 NMEA Network Class and Function Code Definitions.

The NMEA 2000 Committee routinely considers proposed new class/function code definitions for new devices that do not fit into an existing class/function code.

8.2.4.2 Multiple Class & Function Codes

NMEA 2000 devices that use multiple class/function codes, as defined in § 8.3, to segregate the activities of multiple functions within a product, shall claim separate addresses for each unique class and function code. (See Appendix D § D.5.16. for implementation examples).

8.3 Device Information

ISO 11783-5 defines the Address Claimed message PGN 60928 with a data field containing NAME. NAME is a 64-bit entity that in addition to reserved bits includes the fields identified in the following table (Table 5).

<table>
<thead>
<tr>
<th>ISO 11783-5 Designation</th>
<th>NMEA 2000 Designation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industry Group</td>
<td>Industry Group</td>
</tr>
<tr>
<td>Device Class Instance</td>
<td>System Instance</td>
</tr>
<tr>
<td>Device Class</td>
<td>Device Class</td>
</tr>
<tr>
<td>Function</td>
<td>Device Function</td>
</tr>
<tr>
<td>Function Instance</td>
<td>Device Instance Upper</td>
</tr>
<tr>
<td>ECU Instance</td>
<td>Device Instance Lower</td>
</tr>
<tr>
<td>Manufacturer Code</td>
<td>Manufacturer Code</td>
</tr>
<tr>
<td>Identity Number</td>
<td>Unique Number</td>
</tr>
</tbody>
</table>

In addition to the information defined by NAME, NMEA 2000 provides additional Product Information and Configuration Information Parameter Groups.

8.3.1 NMEA 2000 NAME Implementation

8.3.1.1 NMEA 2000 devices shall implement the NAME field, and field dependencies of the Address Claim message as defined by PGN 60928 in the NMEA Network Message Database.

8.3.1.2 NMEA 2000 Device Class (field 7) and NMEA 2000 Function (field 5) of the NAME data fields of PGN 60928 shall be implemented according to NMEA Network Message Database § B.6 – NMEA 2000 Class and Function Codes.
8.3.1.3 Industry Group, Device Class, and Device Function fields can be correlated to a common function definition by the link between the NAME and the address claimed using that NAME. Manufacturers shall use these fields first, in addition to the remaining NAME fields, to determine the meaning of any parameter groups being transmitted from that address. See ISO 11785-5 (Appendix F) Figure 1, Appendix D §3.3.7, and Appendix D §3.3.8.

8.3.1.4 The NMEA 2000 Unique Number is a 21-bit field in the NAME assigned by the product manufacturer. The Unique Number is necessary to ensure that the NAME of every device is unique so that the NAME may be used to resolve address contention. Manufacturers of NMEA 2000 products shall ensure the uniqueness of this number across multiple products of the same function by the same manufacturer through the use of a unique identity number, serial number, or date/time code. This field shall be non-varying with removal of power.

8.3.1.5 The NMEA 2000 Device Instance value represents the combination of the Device Instance Upper Field with the Device Instance Lower Field, and serves to enumerate multiple occurrences on the bus of the same function within the same class. NMEA 2000 devices shall interpret the ISO Function Instance as the “Device Instance Upper Field”. Device Instance Upper is a 5-bit field, that, when combined with the Device Instance Lower field, distinguishes a single device from a group of identical devices, and is associated with a given Function. NMEA 2000 devices shall interpret the ISO ECU Instance as the “Device Instance Lower Field”. The Device Instance Lower is a 3-bit field, that, when combined with the Device Instance Upper field, distinguishes a single device from a group of identical devices, and is associated with a given Function.

8.4 Field Programmability of the Instance Fields
NMEA 2000 devices shall support field programmability of all the system and device instance fields within the NAME entity and data instance fields within PGNs. Field programmability of all types of instance fields shall be done with PGN 126208. NMEA 2000 networks are expected to support many instances of duplicate and or similar devices on the same network. This may include devices such as compasses, engine controllers, navigation receivers, smoke detectors, displays, and more.

NMEA 2000 requires that when changes are made to the contents of any field or fields within the NAME entity of a NMEA 2000 device, that this device, shall, through manual or automatic means, reclaim its address with the new NAME. NMEA 2000 devices shall maintain their modified NAME fields in non-volatile memory. The primary reason for this is so they use the modified NAME upon subsequent power ups of the device in the future.

8.4.1 System Instance
System Instance is a 4-bit field with a valid range from 0 to 15 that indicates the occurrence of devices in additional network segments, redundant or parallel networks, or sub networks. The
System Instance Field can be utilized to facilitate multiple NMEA 2000 networks on these larger marine platforms. NMEA 2000 Devices behind a bridge, router, gateway, or as part of some network segment could all indicate this by use and application of the System Instance Field. Field programmability shall be implemented through the use of PGN 126208, Command Group Function.

8.4.2 Device Instance
Device Instance is an 8-bit value with a valid range from 0 to 255 that provides a means to enumerate the number of like devices (same Class and Function codes) on the NMEA 2000 network. Field programmability shall be implemented through the use of PGN 126208, Command Group Function.

8.4.3 Data Instance
Data instances shall be unique within the same PGN transmitted by a device. Data instances shall not be globally unique on the bus. Field programmability shall be implemented through the use of PGN 126208, Write Fields Group Function. See Appendix D § 5 for an example Data Instance configuration.

Note: The only exception to the data instance rules above is for devices transmitting PGNs 127488, 127489, 127497, 127498 containing an “Engine Instance” data instance field, and 127493 containing a “Transmission Instance” data instance field. Only these specific data instance fields shall be enumerated on a globally unique basis beginning on the Port side with instance number 0 and incrementing towards Starboard.

Devices in Propulsion Class 50 and Function Code 140 shall be the first enumeration sequence (i.e. 0, 1, 2, 3) prior to moving to a different Class and Function Code. Devices of the next Class and Function Code shall continue the enumeration sequence (i.e. 4, 5, 6). Please refer to examples in Appendix D.

8.4.4 Product Information
The Product Information parameter group (PGN 126996) includes:

- NMEA 2000 Database Version
- NMEA Manufacturer’s Product Code
- Manufacturer’s Model ID
- Manufacturer’s Software Version
- Manufacturer’s Model Version
- Manufacturer’s Serial Number
- Certification Level
- Load Equivalency
8.4.4.1 All NMEA 2000 devices shall support the Product Information message containing at a minimum the “NMEA 2000 Version Supported”, “Manufacturer’s Product Code”, “NMEA 2000 Certification Level” and “Load Equivalency Number”.

8.4.5 Configuration Information

The Configuration Information parameter group (PGN 126998) as described in the NMEA Network message Database (Appendix B) includes:

- Free-form field describing the installation location of the device.
- Free-form field providing field notes.

8.4.5.2 NMEA 2000 devices shall support the Configuration Information message.

8.5 Network Neutrality

Network neutrality is the principle that all devices within a Class and Function Code are treated the same.

8.5.1 Any receiving device shall not filter published PGNs transmitted by other manufacturers’ devices.

8.5.2 Any receiving device that utilizes a given data field within a published PGN shall provide the capability to select and process that data field from any source, regardless of the transmitting device’s data and device instances or source address.

8.6 Transmitted/Received PGN List Group Function

A feature of NMEA 2000 network management is the ability of a device to compile a list of both transmitted and received Parameter Groups that are supported by other devices. The Transmitted/Received PGN List Group Function (PGN 126464) is a Group Function parameter group that utilizes the first data field of the message to indicate the function of the message. Two functions are provided:

a) Transmit PGN List providing a list of all parameter groups transmitted by a device,

b) Received PGN List providing a list of all parameter groups received by a device.

8.6.1 Transmitted PGN List

The Transmitted PGN List PGN includes:

- Group Function code set to 0x0 indicating this message is a Transmitted PGN List message.
- Multiple field list of all PGNs that this device is capable of transmitting.
8.6.1.1 All NMEA 2000 devices shall support the Transmitted PGN List message containing all transmitted messages supported by the device, including Data Link and Network Management messages.

8.6.1.2 The Transmitted PGN List message shall be implemented as described in NMEA Network Message Database §B.4 – PGN Report

8.6.2 Received PGN List

The Received PGN List parameter group includes:

- Group Function code set to 0x1 indicating this message is a Received PGN List message.
- Multiple field list of all PGNs that this device is capable of receiving.

8.6.2.1 All NMEA 2000 devices shall support the Received PGN List message containing all received messages supported by the device, including Data Link and Network Management messages.

8.6.2.2 The Received PGN List message shall be implemented as described in NMEA Network Message Database § B.4 – PGN Report.

8.7 ISO 11783-5 Requirements

Table 8-2 summarizes what are recommendations (e.g., “recommended”, “should”, and “may” terminology) in ISO 11783-5 in the sections identified below that are mandatory requirements of NMEA 2000. The terminology “will/will-not and must/must-not” used in ISO 11783-5 in the sections identified in the table below is considered equivalent to the terminology “shall/shall not” used in NMEA 2000.

This table is provided for clarification of terms that are either different between ISO 11783-5 and NMEA 2000, or to highlight a different emphasis between the standards. In instances where a description within this NMEA 2000 Standard is at variance with ISO 11783-5, a device manufacturer shall follow NMEA 2000.

<table>
<thead>
<tr>
<th>ISO 11783-5:2001(E) Requirements</th>
<th>NMEA 2000 MANDATORY Interpretation / Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.3.1 NAME and Address</td>
<td>A device’s NAME <em>shall</em> describe its function and place in the network, and any function on a network can be designated by a NAME.</td>
</tr>
<tr>
<td>4.3.1 NAME and Address</td>
<td>NAME <em>shall</em> be used in arbitration for addresses</td>
</tr>
<tr>
<td>5.1.1 NAME</td>
<td>Each device on the network <em>shall</em> have at least one NAME so the device can be uniquely identified by its function</td>
</tr>
<tr>
<td>5.1.2.4 Reserved Field</td>
<td>The reserved bit <em>shall</em> be set to zero</td>
</tr>
<tr>
<td><strong>5.1.2.5 Change Instance Field Requirement</strong></td>
<td>Any instance field in the NAME shall be able to be changed and be reset. In the case of a single, or first, device class, function or device, the corresponding instance fields should be set to zero to indicate this.</td>
</tr>
<tr>
<td><strong>5.1.2.7 Identity Number Field</strong></td>
<td>The device manufacturer shall ensure that the identity number be unique and non-varying with removal of power.</td>
</tr>
<tr>
<td><strong>6.2.2.3 Address Claim Requirements</strong></td>
<td>The destination address for an Address Claimed message shall be global (255) to “announce” the claim message to all devices on the network.</td>
</tr>
<tr>
<td><strong>6.2.3.1 Address Claimed/Cannot Claim</strong></td>
<td>If a device receives an Address Claimed message claiming its own source address it shall compare the NAME that was received in the Claimed Address message with its own NAME and determine which device has a higher priority NAME, (that is a lower numeric value). … However if it has the lower priority NAME it shall either claim a new address or send a Cannot Claim Source Address message. A network interconnection device shall not use its own address in communications on the network until it has successfully claimed an address.</td>
</tr>
<tr>
<td><strong>6.2.3.2 Time out requirement</strong></td>
<td>A device shall not begin or resume transmitting on the network until 250 milliseconds after it has successfully claimed an address.</td>
</tr>
<tr>
<td><strong>6.4.3.1 Response to a Request for Address Claimed sent to the global address</strong></td>
<td>A device shall always respond to a Request for Address Claimed message directed to the global address with either an Address Claimed message, or if the device has not been successful in claiming an address, a Cannot Claim Source Address message.</td>
</tr>
<tr>
<td><strong>6.4.3.3 Response to a Request for Address Claimed sent to a specific address</strong></td>
<td>A device shall always respond to a Request for Address Claimed where the destination address is equal to the device’s address. The response to the request, the Address Claimed message, shall be sent to the global address (255).</td>
</tr>
<tr>
<td><strong>6.4.3.3 Response to Address Claims of own address</strong></td>
<td>A device shall transmit an address claim if it receives an Address Claimed message with a source address that matches its own, and if its own NAME is of a higher value than the NAME in the claim it received. If the device’s NAME is of a lower priority than the NAME in the claim it received, the device shall not continue to use that address. It shall attempt to claim a different address, and if not successful, it shall send a Cannot Claim Source Address message.</td>
</tr>
</tbody>
</table>
### 6.4.4.1 Address Claim Prioritization

Where a single address is in contention between two devices, priority *shall* be given to the device with the NAME of lower value hence higher priority. The NAME *shall* be treated as an 8-byte value with the most significant bit at the Self-Configurable Address bit for determining numerical value.

### 6.4.4.2.1 Identical addresses

If multiple devices have the same address but different NAME, simultaneous Address Claimed messages will result in bus errors.

### 6.4.4.2.2 Identical NAME

To protect against modules generating bus errors (until going bus off) the following special processing *shall* be used when transmitting claim messages.

After transmitting an Address Claim Message, claim message, the transmitting device *shall* monitor error code information. If the error code indicates a bus error has occurred, any automatic retransmission attempts by the CAN peripheral *shall* be canceled, if possible.

The retransmission of the claim message should be rescheduled after the standard idle period plus a transmit delay. The transmit delay should be calculated using the procedure detailed in clause § 6.4.6.1. (See Figure 8) of ISO 11783-5

### 6.4.5.1 Contention for an address

A device unable to claim an address *shall not* send any messages except for:
- A cannot-claim-source-address message in response to request-for-address-claimed messages,
- The response to a commanded-address message,
- A request-for-address-claimed message.

### 6.4.6.1.1 Self-Configurable Addressing Device Address Claimed

A Self-Configurable Addressing Device *shall* schedule its Address Claimed message after its Power On Self-Test (POST) period plus a transmit delay.

### 9 NMEA 2000 Certification

All products that include a NMEA 2000 interface shall be required to pass the NMEA 2000 Certification Tests. (See Appendix C Certification Criteria and Test Methods). As of this Version of the NMEA 2000 Main Document, Version 2.000, previous certification levels of A & B have been eliminated. All products shall have the same level of certification. The minimum message implementation required for each NMEA 2000 Certification is defined in the following table:
Table 7 Minimum Message Implementation

<table>
<thead>
<tr>
<th>Message Name / Functionality</th>
<th>PGN</th>
<th>TX</th>
<th>RX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Address Claim</td>
<td>ISO 060928</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Product Information</td>
<td>NMEA 126996</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Configuration Information</td>
<td>NMEA 126998</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Request/ Group Function</td>
<td>NMEA 126208</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Command Group Function</td>
<td>NMEA 126208</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Acknowledgment Group Function</td>
<td>NMEA 126208</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Acknowledgment</td>
<td>ISO 059392</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Request</td>
<td>ISO 059904</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>TX/RX PGN List Group Function</td>
<td>NMEA 126464</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Heartbeat PGN</td>
<td>NMEA 126993</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Commanded Address</td>
<td>ISO 065240</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Transport Protocol, Data Transfer</td>
<td>ISO 60160</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Transport Protocol</td>
<td>ISO 60416</td>
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<tr>
<td></td>
<td>See 9.1</td>
<td></td>
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</tr>
</tbody>
</table>

NOTE: NMEA 2000 Certification Level Field (7) of Product Information PGN 126996 shall be set to 2 meaning “Not Applicable”.

9.1 Minimum Implementation of Transport Protocol

For minimum implementation of Transport Protocol (See § 3.1.1.). All devices shall be capable of receiving the ISO Commanded Address (PGN 065240). This PGN contains 9 Bytes of data and can only be sent using the ISO Broadcast Announce Message (BAM) (PGN 060416) and the ISO Data Transfer PGN (060160).

9.1.1 Commanded Address Implementation

If ISO TP.BAM PGN 060416 is received with Commanded Address 065240, the receiving device shall receive and process PGN 060160 containing the Commanded Address PGN.

9.2 Class 1 Certification

Certification of Class 1 devices follows the tests and methods described in Appendix C.

9.3 Class 2 Certification

Certification of Class 2 devices follows the tests and methods described in Appendix C for Class 2 devices. See “§ 3 NMEA 2000 Data Link Layer” for information regarding the application of the DLC field for Class 2 devices.
# 10 Revision History

<table>
<thead>
<tr>
<th>Revision</th>
<th>Date</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.000</td>
<td>Sept 2001</td>
<td>Initial Release</td>
</tr>
<tr>
<td>1.001</td>
<td>Oct 2001</td>
<td>§ 2.4.4.1 changed equation from $\frac{3}{4}$ to .87 to match text definition</td>
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<tr>
<td></td>
<td>Nov 28, 2001</td>
<td>Table 8-2 Corrected text obtained from 11783-5 6.4.3.3. The statement needed to be revised to be correct. ISO was notified.</td>
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<tr>
<td>1.001</td>
<td>Dec 2001</td>
<td>§ 1.3.3 changed Functional Network Size from 254 to 252</td>
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<td>1.001</td>
<td>Dec 2001</td>
<td>§ 8.2.1 added Claimable Network Address Space 0 – 251 for clarification.</td>
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<tr>
<td>1.001</td>
<td>Jan 2002</td>
<td>Updated fig 12 Micro-C pinout – made terminology agree with NMEA designations i.e. Net-S for V+</td>
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<tr>
<td>1.002</td>
<td>Nov 2002</td>
<td>Removed Blank Pages</td>
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<td>1.002</td>
<td>Nov 2002</td>
<td>Fixed paragraph numbering §§ 8.4.1 &amp; 8.4.2</td>
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<tr>
<td>1.002</td>
<td>Nov 2002</td>
<td>Fixed Paragraph Numbering after 8.3 to § 9</td>
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<tr>
<td>1.002</td>
<td>Nov 2002</td>
<td>Corrected Appendix Reference from D to F in § 3</td>
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<tr>
<td>1.002</td>
<td>Apr 2003</td>
<td>§ 9 Minimum Message Implementation changed to NMEA 2000 Certification Levels and reworked to include Level A and Level B</td>
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<tr>
<td>1.002</td>
<td>Nov 2002</td>
<td>§§ 8.4.1.1 &amp; 8.4.1.2 PGN changed to be required by Certification Level A Devices</td>
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<td>1.002</td>
<td>Nov 2002</td>
<td>In § 8.3 Device Information changed table numbering from 8.3.1 &amp; 8.3.2 to 8.3.0.1 &amp; 8.3.0.2 respectively</td>
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<tr>
<td>1.002</td>
<td>Dec 2002</td>
<td>Removed requirement in § 3.1.4.7 Successive new fast-packet messages from the same source address shall be separated in time by a minimum of 10 CAN frames.</td>
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<td>1.002</td>
<td>Dec 2002</td>
<td>§ 2.4.2 Isolation – Revised Diagram and wording of §§ 2.4.2.1 &amp; 2.4.2.2</td>
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<td>1.002</td>
<td>Dec 2002</td>
<td>§ 8.3.1 Field Programmability – revised wording</td>
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<td>1.003</td>
<td>May 2003</td>
<td>Added § 3.2.2.5 clarification for ack of Command PGN.</td>
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<td>1.003</td>
<td>May 2003</td>
<td>Respond in kind 3.1.1.1 added last paragraph pertaining to ISO Request</td>
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<td>1.004</td>
<td>Jan 2004</td>
<td>Change to § 2.4.7.8 Reaction to Power Disturbances</td>
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<td>1.100</td>
<td>Feb 2004</td>
<td>Revision Change for major release</td>
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<td>Apr 2004</td>
<td>Changed 3.2.1.1 to reflect applicability Certification Level to requirement.</td>
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<td>1.111</td>
<td>May 2004</td>
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<td>Sept 2004</td>
<td>Removed “source” from 2.4.7.2.1</td>
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<td>Certification Class 1 and Class 2 added, §s 3.5, 3.6, 9.3 &amp; 9.4 added</td>
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<td>1.111B Sept 2004</td>
<td>Corrected number of §s 8.3.0.1 &amp; 8.3.0.2 to 8.3.1 &amp; 8.3.2 (formatting issue correction)</td>
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<td>1.111B Oct 2004</td>
<td>8.3.2 Product Information updated with respect to add of Load Equivalency field. Minimum requirement changed. § 8.3.2.2 removed</td>
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<td>1.200 Nov 2004</td>
<td>§s 2.7.1, 2.4.7.4 additions to cover “daisy chain” concerns.</td>
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<tr>
<td>1.201 Sept 2008</td>
<td>Added Function Code 110 Alarm Enunciator to Class Code 20 Safety System NMEA Full Suite Changed to 2.001</td>
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<td>1.210 January 2013</td>
<td>Removed Table 8.1 and all references. Replaced Table 8.1 references with Appendix B.6 Class &amp; Function Codes. Added Proprietary PGN text to § 3.4.</td>
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<td>NMEA 2000 data link layer changes</td>
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<td>Cables &amp; connectors section removed and placed in separate appendix I</td>
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<td>2.000 December 2014</td>
<td>Changed backbone length to 250 meters § 1.3.2 and §2.3</td>
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<td>Updated internet reference to GLONASS in Normative Reference Section</td>
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<td>Updated new address for NMEA Office</td>
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<td>Added new requirements in § 3.1.1 regarding ISO multi-packet</td>
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<td>§ 3.6.3 corrected error regarding modulo 8</td>
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<td>Clarified 3 mandatory functions and added new 4 optional functions to § 3.2 Request/Command/Acknowledge</td>
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<td>Added new requirements for Proprietary Message Certification § 3.4.2</td>
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<td>§ 3.4.3 Definer Tag clarified language eliminating duplication from prior § 3.4.1</td>
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<td>Added new language regarding redundancy § 3.7</td>
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<td>Added new requirements for Class and Function Code § 8.2.4</td>
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<td>December 2014</td>
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<td>December 2014</td>
<td>NMEA 2000 NAME Implementation added new language for clarification and new requirements (§ 8.3.1.1 – 8.3.1.5)</td>
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<td>December 2014</td>
<td>Field Programmability added new language for clarification and new requirements</td>
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<tr>
<td>§ 8.4.1</td>
<td>December 2014</td>
<td>System Instance added new language for clarification and new requirements</td>
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<td>§ 8.4.2</td>
<td>December 2014</td>
<td>Device Instance added new language for clarification and new requirements</td>
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<tr>
<td>§ 8.4.3</td>
<td>December 2014</td>
<td>Data Instance added new section with new language and new requirements</td>
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<td>§ 8.4.4</td>
<td>December 2014</td>
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<td>December 2014</td>
<td>Network Neutrality added new section with new language and new requirements</td>
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<td>§ 8.6.2</td>
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<td>§ 9</td>
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<td>NMEA 2000 Certification. Added new language and new requirements. Level A &amp; Level B deleted. Added Note for PGN 126996 Field 7 requirements</td>
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<td>Table 7 added new requirements for minimum message implementation. All devices will need to implement new PGNs in Table 7</td>
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<td>Deleted § 9.4 and Table for Certification of Level A</td>
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<td>Deleted § 9.5 and Table for Certification of Level B</td>
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<td>Deleted § 9.6 and § 9.7</td>
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</table>
11 Appendixes

The following Appendixes follow this document and are part of the NMEA 2000 edition and are separate documents.

Appendix A -- Application Layer (Parameter Group Definitions)

This is now included within Appendix B, the NMEA Network Message Database.

Appendix B -- NMEA Network Message Database

See the Data Base Report Document containing Appendix B §§ B-1, B-2, B-3, and B-4, B-6, B-7

Section B.1 – PGN Table

Except for manufacturer’s proprietary messages, NMEA 2000 application related parameter groups shall consist of only those parameter groups defined by NMEA and listed in the NMEA 2000 Data Base

Section B.2 – Data Dictionary

Each field in an NMEA 2000 message, except manufacturer’s proprietary data, shall be defined by a data dictionary item from Table “DD#_Tbl”

Section B.3 – Data Format

Various physical data are to be communicated on the NMEA 2000 network. Each type of data (e.g., latitude, longitude, time, distance) that is transmitted is formatted in accordance with Table DF#_Tbl. Except for manufacturer’s proprietary data, only data formats defined by Table “DF#_Tbl” - Data Formats shall be transmitted on the network.

Section B.4 – Data Type

All data transmitted on the NMEA 2000 network shall be in one of the forms defined in Table “Type_Tbl”

Section B.5 – Reserved for Future use

Section B.6 – Device Class & Function Codes

Section B.7 – Alert Codes

Appendix C -- Certification Criteria and Test Methods