NMEA 2000® APPLIED

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BACKGROUND

The National Marine Electronics Association (NMEA) completed and released the NMEA 2000® Standard for Serial-Data Networking of Marine Electronic Devices during October 2001. The development of this standard began in 1994. After five years of development, the NMEA 2000® standard was put through an eighteen-month beta test. Manufacturers and government agencies participated in the beta test program, where the standard was physically implemented in a variety of marine electronic equipments. These efforts resulted in clarifications, additions, corrections, and modifications to the NMEA 2000® standard that would not have been otherwise possible. This paper discusses the physical layer (connectors, cables, power, etc) of the standard, basic messaging, certification issues, and includes manufacturers comments concerning application of the NMEA 2000® standard within their equipment.

THE STANDARD

NMEA 2000® is a low-cost serial data network operating at 250 kbits/second utilizing the Controller Area Network (CAN) integrated circuit (IC). CAN was originally developed for the automotive industry, and now is used in numerous industrial applications and produced by dozens of IC manufacturers. Many people are familiar with the NMEA 0183 interface. NMEA 0183 is a serial data interface operating at 4.8 kbits/second utilizing standard asynchronous communications of the type found on the serial port of a PC. The key difference, apart from the obvious one of operating speed, is that NMEA 0183 is an interface and NMEA 2000® is a network.

The NMEA 2000® network allows multiple electronic devices to be connected together on a common channel for the purpose of easily sharing information. Because it is a network, and because multiple devices can transmit data, a more comprehensive set of rules is required that dictate the behavior of the members of the network. CAN automatically provides some of these rules – mostly for control of access to the network, packet transmission, and for error detection. Similar to NMEA 0183, NMEA 2000® defines standard data formats and definitions, but in addition provides more extensive network management rules for identifying nodes on the network, sending commands to devices, and for requesting data.

Besides the greater amount of control and integration provided, NMEA 2000® replaces with a single cable all of the wiring of up to 50 NMEA 0183 interconnections and can handle the data content of between 50 and 100 NMEA 0183 data streams. NMEA 2000® networks operating at 250Kbits may be as large as 200 meters.

CAN vs. ETHERNET

A question often asked regarding NMEA 2000® is, why is it based on CAN? Why not Ethernet? NMEA's desire to develop a low-cost, self-configuring, and multi-master network led to the choice of the Controller Area Network for the network interface. CAN based networks have been used by automotive, textile, and other manufacturing industries for many years. CAN was developed to function in electrically noisy environments, to be robust, reliable, and have a predictable delivery time for any information being moved on the network. Below is a brief table summarizing some of the capabilities and differences between CAN and Ethernet protocols.

Controller Area Network Protocol	Ethernet Protocol
CSMA – Carrier Sense Multiple Access with Non-Destructive Bit Wise Arbitration - A Collision less system that is deterministic – No lost Bandwidth when simultaneous multiple accesses occur.	CSMA – Carrier Sense Multiple Access with Collision resolution being non deterministic – Bandwidth is lost when collisions occur.
All messages are broadcast	Guaranteed point-to-point delivery - you just don't know when
Bandwidth is constrained by the need for each node to sample the bus at the same time - 62.5Kbit to 1Mbit	Large bandwidth -10Mbit and up
Cable length constrained by the need for each node to sample the bus at the same time – 1,100 meters at 62.5Kbit to 25 meters at 1Mbit	Cable length - 100 meters
Multiple error checks on all transmitted messages - CRC, bit stuffing, and all nodes participate in error checking of each transmitted message	
Automatically determines when its node is having repeated errors and will automatically take a node off-line to protect the rest of the network.	
Guaranteed correct message transmission.	
Inexpensive parts due to volume in automotive use.	

THE PHYSICAL LAYER

This layer defines the electrical and mechanical aspects of the physical link between network connections, and references 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:

- Media access uses CAN as defined by ISO 11898.
- CAN utilizes dominant/recessive bit transmission.
- Time delays and network loading limit bit rate and network length.
- Differential signaling improves noise immunity.
- Network single-point common signal reference controls ground voltage levels and reduces RFI.

Differential signaling indicates that powered interface circuits and a signal-reference common to all nodes on the network are required. 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 standard allows the use of the vessel's 12-Volt battery to power the network, if the length of the backbone cable and the number of nodes are small enough. Alternatively, one or more regulated power supplies may be used to power the network.

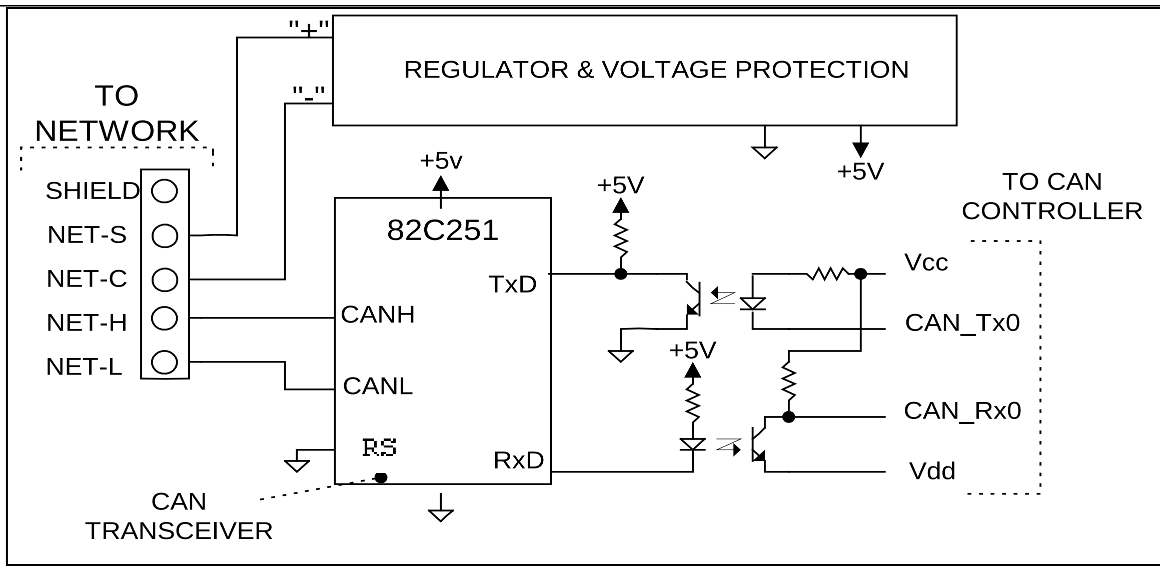
Single-point power and common may be distributed via the network backbone cable as previously required, or for heavier current, by dedicated twisted-pair wires to individual devices. This feature allows equipment to draw additional operating current from the network power source and to be built with minimum interface complexity. In all cases the power and common for the interface circuits must not connect to other power or ground in a network device. This isolation may be achieved in a number of ways. One is by use of isolation circuits (e.g., optoisolators) within the device, either at the interface or at specific places where the equipment connects to other devices. Another way is by assuring that no power or ground connections, other than the network power and network common, connect to the device. The latter method is suitable for equipment such as displays or sensors that have no interfaces other than with the NMEA 2000® network, can draw all of their operating current from the network source, and have isolated packaging and mounting designs.

The figure below illustrates a typical physical layer interface circuit using available transceiver integrated circuits meeting the requirements of ISO 11898. Ground isolation, illustrated with optoisolators, is shown between the network and the CAN controller and other device circuits (e.g., microprocessor and other circuits). However, as pointed out above, isolation from other circuits may be accomplished by other means.

The illustrated transceiver circuit requires regulated +5 Volt power that is provided by the Regulator and Protection circuits. The purpose of the protective circuits is to prevent damage to the regulator and the interface circuits from over voltage and reverse voltage. No permanent damage should result from a voltage level of +/-18.0 Volts or less applied between any two wires in the interface for an indefinite period of time or from miswiring the interface lines in any combination.

ENVIRONMENTAL AND RADIO FREQUENCY INTERFERENCE

NMEA 2000® implementations must meet the Durability and Resistance to Environmental Conditions described in Section 8 of IEC 60945 and meet the Unwanted Electromagnetic Emissions and the Immunity to Electromagnetic Environment conditions of Sections 9 and 10 of IEC 60945. Shielded cables



Typical Isolated Network Interface

are recommended, and may be necessary to meet these latter requirements.

GROUND ISOLATION

AC and DC isolation is required between all of the terminals at the interface connector, with the network cables disconnected, and any other ship's ground or voltage sources. As discussed above this can be accomplished with isolation devices such as opto-isolators or by wiring and packaging design. For most applications, except those with very low power needs, the isolated interface is the preferred implementation.

NETWORK SIGNALING

The two signal lines carry differential signals measured with respect to the network power common. The 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. The interface must be designed so that the signal lines are in the Recessive state when node power is off.

The AC and DC voltage parameters of the network signals are specified by ISO 11898. The nominal voltage levels are:

- Dominant state:
  CAN+ = 3.5V CAN- = 1.5V V_{diff} = CAN+ - CAN- = 2.0V
- Recessive state:
  CAN+ = 2.5V CAN- = 2.5V V_{diff} = CAN+ - CAN- = 0.0V
- Common Mode range:
  Difference in network common voltage between nodes: -2.5 to +2.5 Volts

NETWORK POWER

The interface circuits must operate over the range of 9.0 to 16.0 Volts DC. The voltage for the interface can either be supplied from the network backbone cable or supplied by a dedicated twisted-pair power cable connected only between a single node and the network power source (the vessel’s battery or one regulated power supply). The amount of current delivered by the network cable is limited. When a dedicated power connection is used the node is allowed to draw additional current but the connections must be labeled, and physically separated and isolated from other power and ground connections. Under no condition may the node power or ground be connected to other power or ground in the equipment.

To aid in planning network installations manufacturers are required to specify the power rating for each connected device as a “load equivalency number”. The actual power source for the network can be either a single-point connection to the vessel’s battery or one or more isolated power supplies distributed along the network. The size and routing of the cables must be carefully considered. As the number of nodes with high load equivalency numbers increase, DC voltage loss in the cables quickly becomes the limiting factor for network length rather than the propagation time for the signals. 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, electrically isolated regulated power supplies may be used if it is necessary to extend the size of the network.

CABLES AND CONNECTORS

Two methods are provided for connecting to the network backbone cable: a standard connector or barrier strips. These connections are used for connecting segments of backbone cable together, for connecting terminations at the two ends of the cable, for connecting the network power source, and for connecting nodes. The drop cable, the short cable running from the backbone connection to the node equipment, may connect to the equipment anyway the manufacturer chooses. It is the connections at the backbone that are controlled by the NMEA 2000® standard.

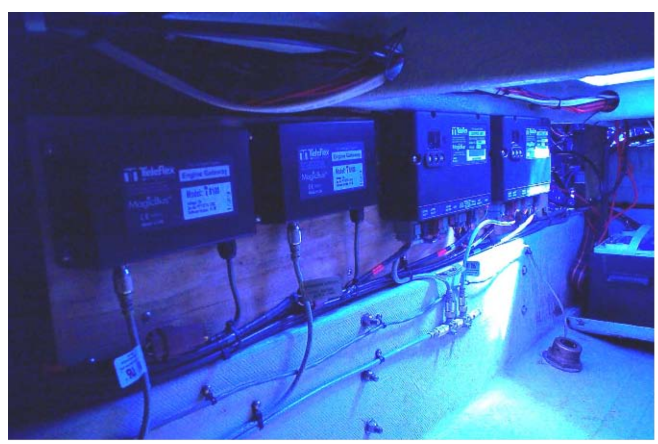
Barrier strips are only recommended when the connections are made in a protected location, or when they are installed in a weatherproof enclosure, thus meeting the requirements for Resistance to Environmental Conditions for exposed equipment in IEC 60945. Barrier strips positions must be either numbered or color-coded in accordance with the definitions in the standard.

The connector selected for the NMEA 2000® backbone is a 5-pin type used in industrial networks and is available from multiple sources (including Molex, Turck Inc., Methode Components, and Daniel Woodhead Company). Two sizes of the connector may be used depending upon the choice of heavy or light backbone cable. The connectors are available as 3-port "T" connectors, cable-end connectors, bulkhead-mount connectors and special configurations with internal termination resistors.

Cable specified for the network must meet both the characteristic impedance and propagation delay requirements for use as a transmission line, and also the wire-size needs of the DC power distribution function of the cable. The cable lengths on the network, the number of nodes connected, the distribution of the nodes, and the location of the power source connection(s) into the backbone cable determine the actual cable requirements in a particular installation. Two cable sizes are specified and can be used as needed in an installation. NMEA 2000® Heavy cable is 5-wire consisting of two shielded-twisted-pairs and a common shield drain wire. The wire pairs are No. 16 AWG (1.33 sq. mm) for DC power and No. 18 AWG (0.83 sq. mm) for signals. NMEA 2000® Light cable uses No. 22 (0.38 sq. mm) and No. 24 (0.24 sq. mm) respectively.

The cable specified has a defined color code, in the event that these colors are not available the substitute cable must be marked according to the standard.

The four photographs below are provided courtesy of Teleflex Morse. The vessel is a 25ft Cherokee with twin inboard engines and electronic shift and throttle controls. There are no mechanical controls between the helm and the engines. This vessel has been operating with this NMEA 2000® based equipment suite since April 18th 2001, supporting local law enforcement activities. The upper left photograph depicts the helm of the boat. All instrumentation (Teleflex i5500 Displays for engine monitoring) and engine shift and throttle controls are connected to the NMEA 2000® network. The upper right picture shows the twin 8.1 liter GM Crusaders Engines controlled by the network. The lower left picture shows the two Teleflex i6000 Engine Control units. Each Engine Control Unit is connected to the NMEA 2000® network via a drop cable and a "T" connector. One end of the NMEA 2000® network is terminated in this picture. The other terminated end of the network is not shown. The lower right picture shows the two Teleflex i8105 Engine Interface Units along side the Engine Control Units. The drop cables for the Engine Interface units connect to the same NMEA 2000® network via "T" connectors. These drop cable network connections are not visible in this picture. See http://www.tfxmagicbus.com for more information on this platform or Teleflex Morse products with NMEA 2000®.



MESSAGE BASICS

Messages transmitted on the network are organized into parameter groups that are identified by a parameter group number (PGN) that appears in the CAN identifier field as either an 8-bit or 16-bit value depending on whether the parameter group is designed as an addressed or a broadcast message. Depending on the amount of data, the parameter group may require one or more CAN frames to transmit the data. The data content for all parameter groups is structured in an organized way using a database containing a number of tables. Data fields are constructed in the following way:
Each data field has a description defined by a data dictionary entry. Data dictionary items are re-used in as many parameter groups as possible. An example of a data dictionary item is:
Wind Direction, True – Direction from which the wind blows. Degrees relative to true north.

Each data dictionary item is of a defined format, usually representing the physical parameter being defined. Physical parameters are finite so there are fewer data format entries than data dictionary entries. The data formats are based upon the International System of Units (SI). In the case of "Wind Direction, True" the data format is:
Angle: Units = radian, range = 0 to 2π, resolution = 1×10^{-4}

A standard data type such as Character, Integer, Unsigned Integer, Float, or Bit Field represents every defined data format. The data type for "Angle" is:
uint16: 16-bit unsigned integer, range 0 to 65, 532. 65,533 = Reserved. 65,534 = Out of range. 65,535 = Data not available.

The information necessary to describe a parameter group is illustrated below in the Parameter Group Definition table for Distance Log Data. The data represents the cumulative voyage distance traveled. This NMEA 2000® message is a global broadcast message (Destination = Global) with a default priority level of "6", the application that is running may change the priority level over the range 0 to 7. This message requires fourteen data bytes and is not a single-frame message.

The Distance Log Data message is a fast-packet message requiring 3 CAN frames. The message consists of 4 data fields spread over the 3 frames. The boundaries of the data fields with respect to the CAN frames have no significance and it is a task of the receiving node to reassemble the fields from the received frames. The time and date may be initialized or modified by setting data fields 1 and 2 with the Command Group Function message. If the device does not know the time and date when this PGN is generated, than the time and date fields should indicate this with the appropriate values. For a uint16 data type, as in the Date field, the value that indicates "Data not available" is 65,535. For a unit32 data type, as in the Time field, the value that indicates "Data not available" is 4,294,967,295. Definitions for the information in all 4 data fields are provided in the Data Dictionary.

Distance Log

PGN: 128275

This PGN provides the cumulative voyage distance traveled since the last reset. The distance is tagged with the time and date of the distance measurement. The distances through water are accumulated and the values stored during power down and resume counting after power up.

- Total Cumulative Distance is normally set to zero when the log is installed and never reset after that.

- Distance Since Last Reset may manually be set to zero at any time during the voyage and starts to count up from there.

- The "Distance Since Last Reset" is reset by setting the "Distance Since Last Reset' value to 0 with the "Command Group Function" PGN 126208..

Single Frame: No *Priority Default:* 6 *Default Update* 1,000milliseconds *Frequency:* 1.cycles per second

Destination: Global *Query Support:* Opt'l *ACK Rqmnts:*

Field *Field Name* Original Reference ID # 39

1 **Measurement Date** *Byte Field* 2 *Bit Field* *Request* No

DD039 Generic date Days since January 1, 1970, Date is relative to UTC Time. *Size:* *Parameter*

DF41 Date, day count **uint16** *Range:* 0 to 65,532 days *Resolution :* 1 day 0 = January 1, 1970, max = ~179 years

2 **Measurement Time** *Byte Field* 4 *Bit Field* *Request* No

DD158 Generic time of day 24 hour clock, 0 = midnight, time is in UTC *Size:* *Parameter*

DF06 Time of day **uint32** *Range:* 0 to 86,401 s *Resolution :* 1x10E-4 s ~24 hours, 0 = midnight, range allows for up to two leap seconds per day

3 **Total Cumulative Distance** *Byte Field* 4 *Bit Field* *Request* No

DD120 Distance, voyage *Size:* *Parameter*

DF11 Distance, long **uint32** *Range :* 0 to ~4.295x10E+7 *Resolution :* 1 m

4 **Distance Since Last Reset** *Byte Field* 4 *Bit Field* *Request* No

DD120 Distance, voyage *Size:* *Parameter*

DF11 Distance, long **uint32** *Range:* 0 to ~4.295x10E+7 *Resolution* 1 m

NMEA 2000® MESSAGES

A list of parameter groups (messages) as of version 1.000 is provided below for reference. Since new messages are continually being added, this list should be used only as an example of the type of messages that are provided by NMEA 2000®

APPLICATION PARAMETER GROUPS

- Attitude
- Battery Status
- Bearing and Distance between two Marks
- Binary Switch Bank Status
- COG & SOG, Rapid Update
- Cross Track Error

- Current Station Data
- Datum
- DGNSS Corrections
- Direction Data
- Distance Log
- DSC Call Information
- Engine Parameters, Dynamic
- Engine Parameters, Rapid Update
- Engine Parameters, Static
- Environmental Parameters
- Fluid Level
- GLONASS Almanac Data
- GNSS Control Status
- GNSS Differential Correction Receiver Interface
- GNSS Differential Correction Receiver Signal
- GNSS DOPs
- GNSS Position Data
- GNSS Pseudorange Error Statistics
- GNSS Pseudorange Noise Statistics
- GNSS RAIM Output
- GNSS RAIM Settings
- GNSS Sats in View
- GPS Almanac Data
- Heading/Track Control
- Loran-C Range Data
- Loran-C Signal Data
- Loran-C TD Data
- Meteorological Station Data
- Moored Buoy Station Data
- Navigation Data
- Position, Rapid Update
- Radio Frequency/Mode/Power
- Rudder
- Salinity Station Data
- Set & Drift, Rapid Update
- Small Craft Status
- Speed
- Switch Bank Control
- System Time
- Tide Station Data
- Time & Date
- Time to/from Mark
- Tracked Target Data
- Transmission Parameters, Dynamic
- Trip Parameters, Small Craft
- User Datum Settings
- Vessel Heading
- Vessel Speed Components
- Water Depth
- Wind Data

NETWORK MANAGEMENT PARAMETER GROUPS

- Acknowledgement, basic
- Acknowledgment Group Function
- Address Claim
- Address, Commanded
- Configuration Information
- Command Group Function
- Product Information
- Proprietary, Addressed
- Proprietary, Global
- Received PGN List Group Function
- Request, basic
- Request Group Function
- Transport Protocol, Connection Management
- Transport Protocol, Data Transfer
- Transmitted PGN List Group Function

NMEA 2000® CERTIFICATION

The National Marine Electronics Association provides a self-certification tool to aid manufacturers in testing their product(s) during development and prior to final release. The NMEA requires that any device providing a NMEA 2000® interface must pass the self-certification test before that product may claim that it offers NMEA 2000®. This is to ensure that all NMEA 2000® based devices implement the network protocols properly. This testing also ensures that the automatic self-configuring capabilities defined by the NMEA 2000® standard are properly implemented and do not for any reason, cause or generate problems for other equipment on the network. The testing is designed to expose any flaws or weaknesses in the NMEA 2000® protocol implementation and ensure that all devices from all manufacturers behave in a known and predictable manner on the network. This testing does not validate the data or measurements provided by a device, only how it interacts on the network.

The certification tool consists of both hardware (a dual CAN pc-card, cables, and network terminators) and software that runs under several variants of the Microsoft Windows operating systems. The software is designed to walk the user though all required tests. Some tests require physical measurements (such as voltage levels or ground isolation) and are referred to as manual tests. The software prompts the user for the information needed for each manual test and stores the information in a database. At any time, the user can instruct the software to conduct the many network protocol tests; these are referred to as automated tests. The results of these tests are added to the test database on the users PC. The user can observe the results of each test on-screen, and is provided with an ASCII file of the complete test results. In order to receive certification, the encrypted test data base file must be sent to NMEA for validation. Only after a device has passed all the tests successfully, and NMEA has validated the results, can a device be NMEA 2000® certified.

What Is The Certification Process?

Within the NMEA 2000® document package, Appendix C deals with all issues of required certifiable functions and mandatory product characteristics. A manufacturer wishing to claim any product to be NMEA 2000® compliant will need to perform the following steps:

1) Obtain a Manufacturer Code from NMEA:
   The Manufacturers Code is a component of something called the device's NAME. A device's NAME is the composite of several bit fields, one of which is the Manufacturers Code. The NAME consists of a 64-bit numeric value that contains unique information about a device. The numeric value of the device's NAME is directly related to priority. Each device's NAME is used to arbitrate network addresses for each network device. An automated procedure, Auto-Address Claim, used to obtain network addresses for each device, is dependant upon the existence of a unique NAME value for every device on the network. NMEA manages the assignment of these codes to

ensure that each manufacturer receives a unique code. A device cannot be certified with out a manufacturer's code.

2) Register each product with NMEA that is to be considered for certification.
NMEA in return provides the manufacturer with a product code. The product code is used within the manufacturer's device. This provides a powerful yet simple capability to identify a device on the network by asking for it's manufacturer code and product code. A device cannot be certified with out a product code.

3) Obtain a NMEA 2000® Certifying Tool from NMEA.
The certifying tool enables a manufacturer to perform all self-test steps and submit result to NMEA for final approval of certification. The manufacturer need only purchase the tool once, and may use it across any and all product lines during development and when requesting certification validation.

4) Request certification validation.
Once a product has been completed, the manufacturer may request a certification validation. In order to do this the manufacturer must first execute the certification tool, which generates a binary data file. The manufacturer submits this file to NMEA for validation review. NMEA will review all certification submissions to verify that minimum requirements identified in Appendix C are properly satisfied. The NMEA will then either grant the manufacturer permission to use the "Certified for NMEA 2000®" Logo, or open a dialog with the manufacturer to address any certification issues needing further attention.

5) NMEA will maintain a section on its website with lists of manufacturers and their NMEA 2000® certified products.

Without a manufacturer number, a product registration number, or a certification validation, a product will not be able to correctly function on a NMEA 2000® network, nor legally use the copyrighted term NMEA 2000® Certified, or the "Certified for NMEA 2000®" Logo.

This process is intended to ensure that all products coming onto a NMEA 2000® network have properly implemented the NMEA 2000® protocol. Proper behavior on the network ensures that devices will be able to safely and accurately communicate and share data with all other certified products.

Below are two pictures of the NMEA 2000® Certification Tool. The close-up picture shows the PCMCIA Dual CAN Card manufactured by Kvaser for NMEA. The card plugs into a notebook utilizing the Microsoft Windows Operating Systems (Win 98, ME, 2000, XP). Dual CAN busses are needed to conduct the comprehensive certification tests. The other picture shows the card with all the cables connected. The device under test would be connected somewhere along the cable that disappears off the table in the picture. What is not shown is a picture of the accompanying software operating on the PC that the card would be plugged into.

KNOWN MANUFACTURERS HAVING PRODUCTS CURRENTLY UNDER DEVELOPMENT WITH NMEA 2000® CAPABILITY

- Teleflex
- Raymarine
- Simrad
- Kvaser
- JRC
- Navionics

QUOTATIONS FROM SOME MANUFACTURERS CURRENTLY IMPLEMENTING NMEA 2000® NETWORK CAPABILITY INTO PRODUCTS

QUESTION ASKED BY NMEA:
What do you consider to be important about NMEA 2000® for your product/s or product line?

Peter Long of Raymarine:
With the use of NMEA 2000® technology Raymarine will provide systems solutions in our future product lines that will share and distribute information with a high degree of integrity meeting the ever increasing demands of modern boating."

Federico Sturlese of Navionics:
"The NMEA2000 standard - like any other open standard - is fundamental for any company, like Navionics, who manufacture instruments that are not designed to work as a stand-alone unit or in conjunction with instruments belonging to the same brand. In our case, the chart plotter is the central unit of a wider system that is composed - at a minimum - of GPS, autopilot, wind instrument and echo sounder. Unless one makes all of them, like - for instance - Raymarine or Furuno, there is a need of a networking standard that is open and can be used by all manufacturers. This is also in the interest of the customer, as he can choose the instrument that best fits his needs, regardless of the brand. I believe that you - as a customer - would be more happy if you knew that you can choose a plotter from Furuno and connect it to an echo sounder from Raymarine, maybe because it features a very peculiar function that you don't want to miss."

John Larsen of Simrad:
"The things we consider important about this new NMEA 2000® standard are 1) the easy system configuration of all electronic products for a modern advanced boat, 2) the ease of installation because of the use of standard cables, and 3) easy system set-up after installation."

Junji Takita of Japan Radio Company (JRC)
"I believe the important points about NMEA 2000® are as follows:
1) It is a Universal Interface standard similar to NMEA 0183. (Virtually every manufacturer's sensor data can be handled by NMEA 2000®.)
2) It should have high reliability (it is maintenance free and should not have trouble under any condition.)
3) It is low cost; in development, certification, product and installation etc.)"

QUESTION ASKED BY NMEA:
How do you evaluate the complexity of implementing NMEA 2000® as a technology within your company?

Federico Sturlese of Navionics:
"As for the complexity of the NMEA 2000® technology, this is of course an order of magnitude higher than the previous NMEA 0183, however the complexity of a network is inevitably higher than a serial link. Yet I believe that it is a bit more over-engineered than it could have been if we had agreed on a few more

trade-offs during the design phase. I am pretty sure that if any of the attending companies had developed a proprietary standard, the result would have been less complex, maybe less flexible, but probably more "practical". However, I do not want to be critical, it is just a remark to outline that the implementation of a NMEA2000-compatible system is not a task that should be underestimated by a company."

John Larsen of Simrad:
"The complexity of NMEA2000 is a giant step compared with NMEA 0183, and the resources for a company to implement NMEA2000 from scratch are quite comprehensive. The minimum demands for a product to be allowed on NMEA2000 are rather high, e.g. minimum message implementation (all packet types) NMEA 2000® will most likely only be implemented in new products (due to new hardware, software and connectors). Therefore it will take some time to get the full benefit of it."

Peter Long of Raymarine:
"Raymarine engineering skills can easily be applied to the integration of NMEA 2000® within the next generation of our products and product lines."

Junji Takita of Japan Radio Company (JRC)
"We don't find a high degree of complexity in implementing NMEA 2000® technology into our company providing this technology has broad support by other product manufacturers and that the implementation cost remains low."

COOPERATION WITH OTHER ORGANIZATIONS

NMEA has frequently cooperated with other industry associations and organizations over the years. However, in the case of the NMEA 2000® Standard, NMEA is even more intricately connected to several organizations that are important to mention.

At one level NMEA 2000® is very closely associated with ISO (International Organization for Standardization) and SAE (Society of Automotive Engineers) because of our sharing common technology between standards. NMEA 2000® in its original conception was based on technology already proven and used by these two organizations. By mutual understanding NMEA, SAE, and ISO have agreed that it is beneficial to keep our CAN based network standards in alignment with each other and compatible for the benefit of our member constituents. There is a lot of work required on the part of all of these organizations to maintain this high degree of cooperation. However, the benefits are important such as; 1) crossover information sharing available to manufacturer's products, 2) economies of scale with common components and design similarities, and 3) NMEA 2000® devices may be used in SAE J1939 networks and ISO 11783 networks, and SAE J1939 and ISO 11783 devices can function within a NMEA 2000® network.

At another level NMEA cooperates closely with the IEC (International Electrotechnical Commission), which is based in Europe, for the purpose of offering a standard for the entire world user base not just users in America. The IEC makes important contributions into various elements of NMEA standards in total, not only the NMEA 2000® standard. The IEC 61162-1 and 61162-2 Standards are Internationally recognized versions of NMEA 0183 and NMEA 0183 HS. The IEC is currently drafting 61162-3, an international version of NMEA 2000®.

TRAINING SEMINARS

Later this year NMEA will be offering several two or three day training seminars for manufacturer engineering staff that will be conducted in different regions of the country. The purpose of these seminars is to provide a "jump-start" course in implementing NMEA 2000® technology within your own company and its products. Announcement of specific dates and requirements for these upcoming seminars will be made during the summer of 2002.

Other seminars aimed at educating and informing dealer technicians and installing staff will be conducted at appropriate venues where dealers typically participate. The first of these seminars will be held during the NMEA Annual Convention at Ft Myers, Florida in October 2002.

NMEA 2000® NETWORK STANDARD WORK IS OPEN FOR NEW MEMBERS

A NMEA 2000® Standard Working Group is now being formed to maintain and continue future development of this exciting new standard. Anyone having interest in joining this ongoing important development may contact Steve Spitzer for further details.