Georgia Hilton
Beginner's Guide to Integration
CaptainGeorgia.com
geo@captaingeorgia.com
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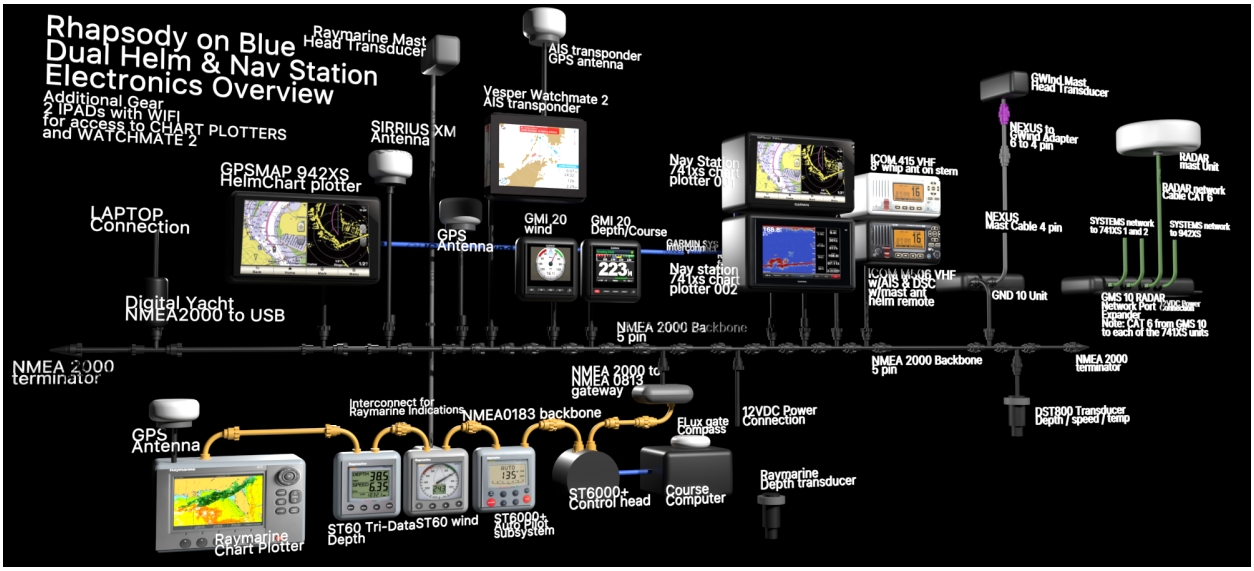
Beginner's Guide to Boat Systems Networking



NMEA

Most of the new instruments, MFDs, and ChartPlotters for boats are now coming out with NMEA 2000 as the preferred method of connecting various devices on a boat, making it significantly easier to network devices and share information. When it comes to networking there are some basic versions out there that all revolve around the NMEA 2000 convention.

Why Network?

Let's discuss my sailboat for an example: a 39' Sloop.

The idea of networking your gear is to help provide you with the number one item while sailing.

SITUATIONAL AWARENESS

Most cruising sailors have a Chartplotter or MFD on board.
It could be a "real" Chart plotter, or "real" Multi Function Display or it could be an IPAD , IPHONE or other smart device with some APPs.

Putting all the available data at your finger tips, easily available is the key.

On my boat, I have an MFD in the Cockpit and 2 smaller MFDs at the NAV station. I want all my info sent to all 3 of these devices. On my boat, as I sail the East Coast of the US, I have some basic Navigation and Safety data being collected by various devices on board.

My Location and status (GPS, speed, heading)
Environmental Data (Wind, Depth, Barometer, Weather)
Traffic Data (AIS and RADAR)

I want to share this data from these devices to my MFDs, my Auto Pilot, and out to other ships in the area via VHF DSC and AIS. I've chosen MFDs over chart plotters as I want more information than just a chart at my fingertips, both in the Navigation Station and the Helm. A NMEA2000 network allows for this.

I created a NMEA2000 backbone connecting the following equipment:

- 3 Garmin MFDs
- 1 NMEA0183 gateway
    - Raymarine Chartplotter
    - Autopilot w/controls
    - Fluxgate Compass
    - Wind Sensor w/indicator
    - Depth Finder w/indicator
    - Speed & Log Sensor w/indicator
- 1 Vesper Marine Watchmate 2 - AIS transponder
- 2 VHF radios with DSC
- 1 Garmin RADAR
- 1 Garmin multi-function display
- 1 Garmin Depth finder
- 1 Garmin Wind sensor
- 1 Yacht Devices USB gateway (for my computer)
- 1 Yacht Devices Barometer
- 1 Yacht Devices WiFi gateway

NMEA

NMEA background

NMEA stands for National Maritime Electronics Association. https://www.nmea.org/

NMEA 2000 has been created to meet a wide variety of needs. It is produced by the marine electronics industry as an ***Industry Open Standard***.

One important requirement is to provide for ***mission-critical data with multiple priorities***.

This requirement is addressed through proper application of ***multiple message priority levels.***

All certified NMEA 2000 devices must demonstrate the ability to adhere to NMEA 2000 requirements through automated software testing and validation.

Like Ethernet, CAN operates in the ***Carrier-Sense/Multiple Access Mode*** (CSMA)

The components of an NMEA 2000 network

Physical Layer - the actual pieces: cables, connectors, terminators, power and electrical characteristics.

Data Link Layer. Defined by ISO with additional requirements specified by the standard.

Network Layer. How the network operates. NMEA 2000 utilizes the CS/MACD protocol

Network Management. Defined by ISO with additional requirements specified by the standard.

Application Layer. Fully defined by the standard and includes a provision for manufacturer's proprietary messages.

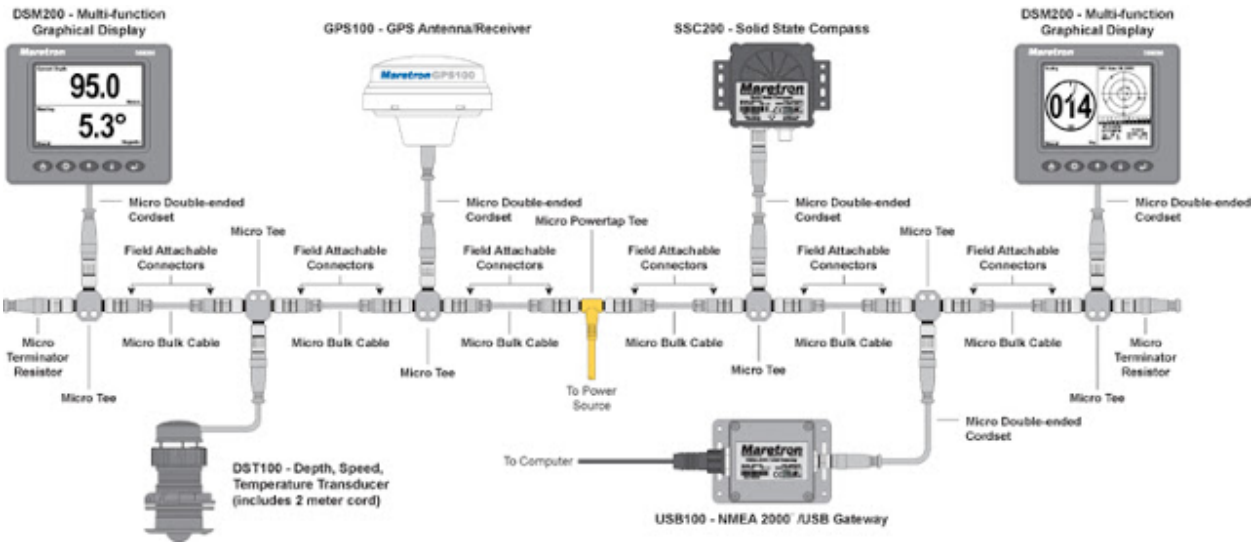
Basic Network Implementations

There are literally dozens of different ways that electronic devices can communicate with each other: through Ethernet, HSB, NavNet, SeaTalk, SimNet, Smartcraft, and USB, to name a few, but the newest of marine instrument integration systems is NMEA 2000.

NMEA 2000 and NMEA 0183 are not a collection of parts and pieces… They are a rule book. A set of International standards. For one thing, the NMEA 2000 rule book specifies which wires and cables should be used, making it much easier to connect equipment from different manufacturers. But a far more fundamental point is that it allows as many as 50 different devices to be connected to a single backbone. Any of them can pump data into the backbone, and any of them can take data from it. It's a true network.

NMEA2000

The NMEA 2000 transmits data through Controller Area Network (CAN bus). It simplifies the connection and shares information among different devices by using a single trunk cable. The standard was designed and developed by Bosch for the automotive market but with messages/sentence appropriate for the marine industry. NMEA2000 Is a multi-talker, multi-listener approach using serial data at moderate date rates (250 kb/s). Basically NMEA200 is a backbone based Local Area Network (LAN) using CSMA/CD (Carrier Sense Multiple Access / Collision Detect) protocol.

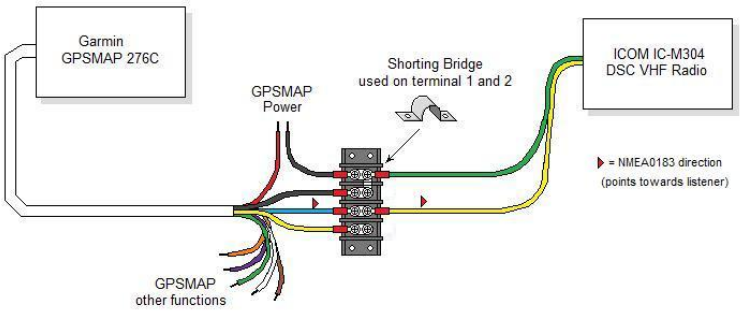


NMEA 2000 Network example

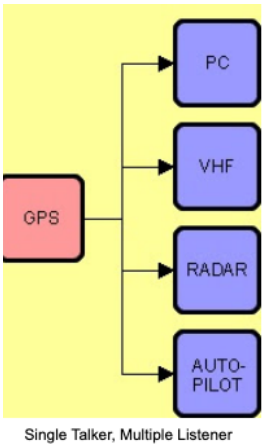
NMEA2000 running at 38.4 Kilobytes / second is 50 times faster than NMEA0183 which runs at 4.8 Kilobytes / second. Typically NMEA2000 supports up to 50 devices on a single network.

NMEA0183 / SEATALK I

NMEA 0183 in “RS422” interface, NMEA 0183 is a low-cost, low-capacity, single-transmitter/ multi-receiver network for interconnecting marine electronic devices, also known as a “single talker/multiple listener” interface. Basically Point to Point, or Hub based.



NMEA0183 example

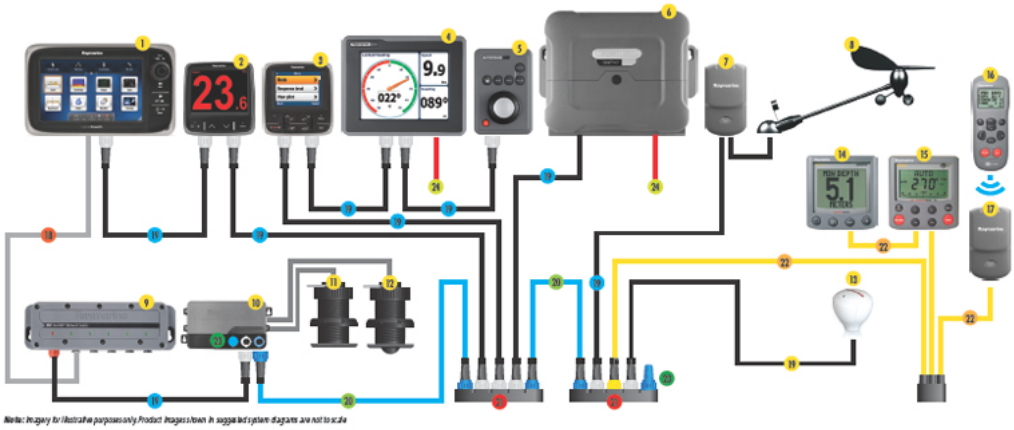


Single Talker, Multiple Listener

The NMEA 0183 Standard, along with RS-232, RS-422, etc., is often called “Asynchronous Serial” interfaces. This means that data is transmitted serially (bit-by-bit) on a single line. Furthermore, the transmission is asynchronous because no “clock” signal is transmitted with the data. SEATALK I (now out of date) uses a NMEA 0183 format. NMEA0183 supports 5 units (one talker and 4 listeners) per network.

SEATALK (ng)

SeaTalkng is an interconnection bus created by and for Raymarine products. Small diameter cable connectors are used throughout the system to make installation easier. There's a wide range of cable lengths, all with over-moulded plugs, so there is no need to cut or splice cables. Spur cables connect individual SeaTalk ng products to the SeaTalk ng backbone.NMEA 2000 / SeaTalk ng All current Raymarine MFDs are NMEA2000 certified.



SEATALK (ng) Network example

Different Manufactures implement NMEA0183 and NMEA2000 differently.

Several major manufacturers use their own systems for interconnecting their own products and their own variants on the generic systems:

Furuno CANbus: Name for its NMEA 2000 system (electronically compatible with NMEA 2000 but with some differences in the way components can be connected

Furuno NavNet: Brandname for its Ethernet system

Garmin Marine Network: Brandname for its NMEA 2000 system

Raymarine SeaTalk I : Proprietary system

Raymarine SeaTalk HS: Brand name for its Ethernet system

Raymarine SeaTalk NG: Brandname for its NMEA 2000 system (electronically compatible with NMEA 2000 but with different connectors)

Simrad SimNet: Brandname for its NMEA 2000 system (electronically compatible with NMEA 2000 but with different connectors)

SmartCraft: Mercury/Mercruiser/Cummins' own system

Teleflex Magic Bus: Brand name for its NMEA 2000 system

There are also different Manufactures of NMEA2000 sensors and equipment

There are a number of companies that makes many sensors for NMEA2000 and NMEA0183

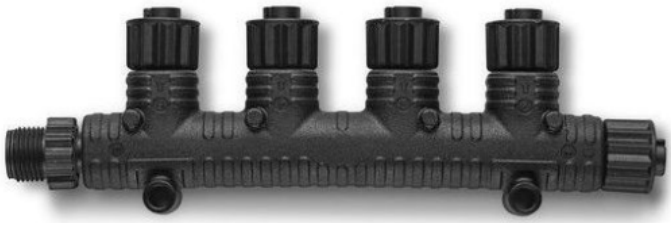
- Digital Thermometers, Digital Barometers, Humidity Sensors
- Water tank, Fuel tank, Grey and Black water tank sensors
- Computer interconnects / USB to NMEA2000 / WiFi gateways / WiFi Routers
- Engine data Gateways / Exhaust Sensors
- Cameras
- NMEA 0183 to NMEA 2000 interconnects (gateways)
- Control Circuits / Relays
- Voltage and/or Current sensors
- Alarms and horns
- Voyage Recorders
- Rudder Indicators
- Text Displays

Setting up a NMEA2000 network

Physical Layer parts

First let's chat about generic pieces parts on a NMEA2000 network.

- Backbone cable
- T-Connector types
- Multi-Connectors
- Cable Terminators (male and female)
- Drop cable
- Power connection
- Hubs
- NMEA 0183 to NMEA 2000 interconnects (gateways)
- Sensors / Devices



CABLE and CONNECTORS

NMEA 2000 / NMEA0183 GATEWAYS, BRIDGES

(bi directional access)

- Manufacturer Engine Gateway
- Wifi Gateway
- NMEA 0183 to NMEA 2000 gateway
- NMEA 2000 to USB gateway
- NMEA to Ethernet
- NMEA2000 Network to Network Bridge

Sensors

- Digital Thermometers, Digital Barometers, Humidity Sensors, Water Temp
- Water tank, Fuel tank, Grey and Black water tank sensors
- Computer interconnects / USB to NMEA2000 / WiFi gateways / WiFi Routers
- Engine data Gateways
- Exhaust Sensors
- NMEA 0183 to NMEA 2000 interconnects (gateways)
- Control Circuits / Relays
- Voltage and/or Current sensors
- Alarms and horns
- Heading Indicators / Flux gate Compass
- Voyage Recorders
- Rudder Indicators
- Text Displays

NMEA2000 Network Devices

- Wind direction / Wind Speed Indicator (True/Apparent)
- GPS Receivers
- XMRadio
- Depth Finder
- RADAR
- Cameras (Standard, Thermal Imaging, Night Vision)
- VHF / DSC
- AIS Receiver / Transceiver
- Auto Pilot / Helm Controls

Multifunction Displays / Chart Plotters and other devices

Configuring Your NMEA Network

Designing Your backbone

The first step is taking a look at what systems and gear you have on board and where that gear is physically located. If it's all in one place you may want to consider a NMEA2000 "Hub". If there are bits and pieces all over the boat you'll want a backbone cable system. Remember, they are not mutually exclusive. You can set up a backbone cable that runs around your boat and connects to a hub located in your Nav station and perhaps another near any cluster of gear you may have. You do need to keep in mind some "rules" (Standards) that have to be met.

NETWORK TOPOLOGY

The distance between any two T-Connectors can not exceed 328 ft (100 m)

Note: 80 ft (25 m) is where you want to stop for best performance. As the cable length starts to exceed 25 m heading up to the maximum, speed of the network will decline from 1000 kbits/sec to 62.5 kbits/sec

The standard minimum of 250 kb/sec will be easily met under 160 ft (50 m)

The Maximum cable length for a network is 3608 ft (1,100 m)

The Maximum number of devices on the network : 50

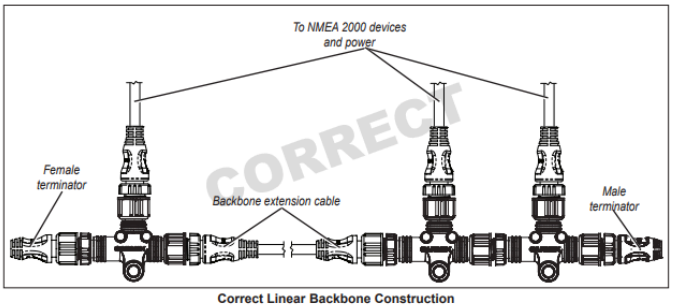
The Maximum length of a drop cable (between the T-Connector and a device is 20 ft (6 m)

The Maximum cumulative drop cable length must be less than 256 ft (78 meters)

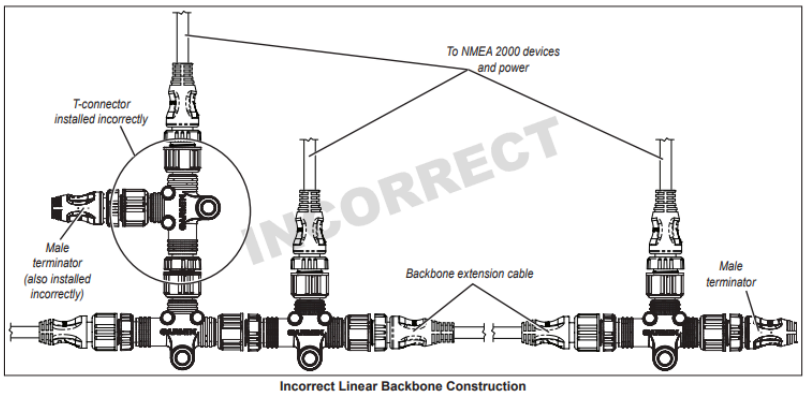
You must have a power connection on the cable/hub for network powered devices (12 VDC)

(Higher end systems can have multiple busses and multiple power supplies for redundancy)

It's critical to create a LINEAR network backbone. The connectors will allow you to incorrectly connect so be careful.



Correct Linear Backbone Construction



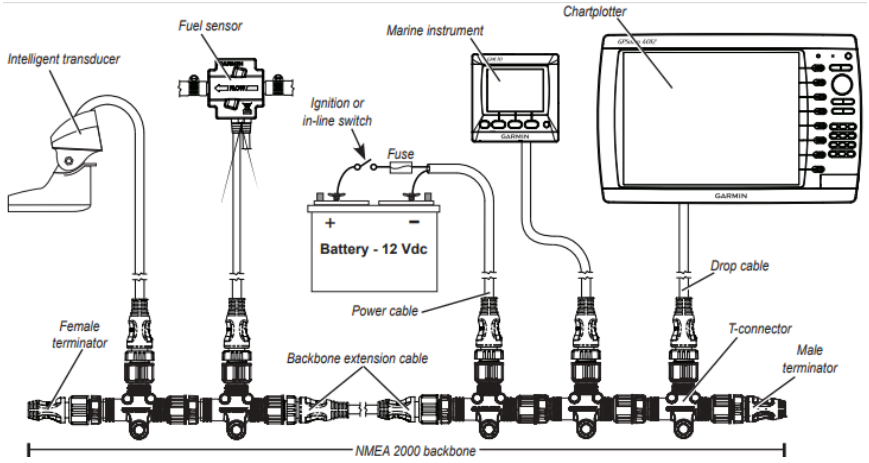
Incorrect Linear Backbone Construction

Powering Your Network

NMEA 2000 networks require 12 VDC but must (based on standards) operate properly between 9 VDC and 16 VDC

NMEA 2000 backbone power is provided using one of the following means:

The vessel's 12-volt battery may be connected via the vessel's DC supply system to the backbone power connections. Only one connection is provided, which may be located at **either end of the backbone** or at **any point along the backbone**. You may also power it from as 12 VDC isolated power supply running from an AC power system.



Make sure you place your power in the center of the backbone. You CAN move it to an end, but there are some issues with doing so. If you place your power connection at one or the other end of the Network backbone and it's a larger backbone there will be a voltage drop issue you need to be aware of. It may not be an issue, most of the time, but if your boat's voltage drops a bit you can get some serious flaky operations or components can be damaged.

Voltage Drop = .053 (cable resistance) x (the distance for each piece of backbone cable added together) x (network load (device usage added together)) x .01

or

Voltage drop = cable resistance x cable length x device load x .01

Note: INSTALL A SWITCH between your battery and your NMEA 2000 power connection!

Note: Make sure you ground you network (some networks have a specific ground wire) to the same place as you negative for your 12VDC power.

NMEA 2000 network build checklist

1. Is the Network configured in a Linear fashion?
2. Is the overall network cable length less than 3000 ft (1,000 m)?
3. Is the distance between any T-connectors less than 300 ft (100 m) ?
4. Are all drop cables less than 20 ft (6m)?
5. Did you install terminators on both ends of the network?
6. Is the network properly powered (12vdc)
7. Did you install a switch between boat power and the network?
8. Did you ground the network properly ?

Mast height issues

Your sailboat mast is way longer than 20 ft (6 meters)….
Most Wind sensors are on the top of your mast.
To overcome this issue, you can run a NMEA2000 backbone cable up the mast and terminate it at the top of the mast. Make sure that the terminator is within 20 ft (6 m) of the last device (your wind sensor). Run the backbone own to a T-Connector at the base of the mast inside your boat. From there continue the NMEA2000 throughout your boat. (be aware of your manufacture cable configurations as some manufactures install terminator resistors on cables longer than 20 ft.)

Connecting Your Devices

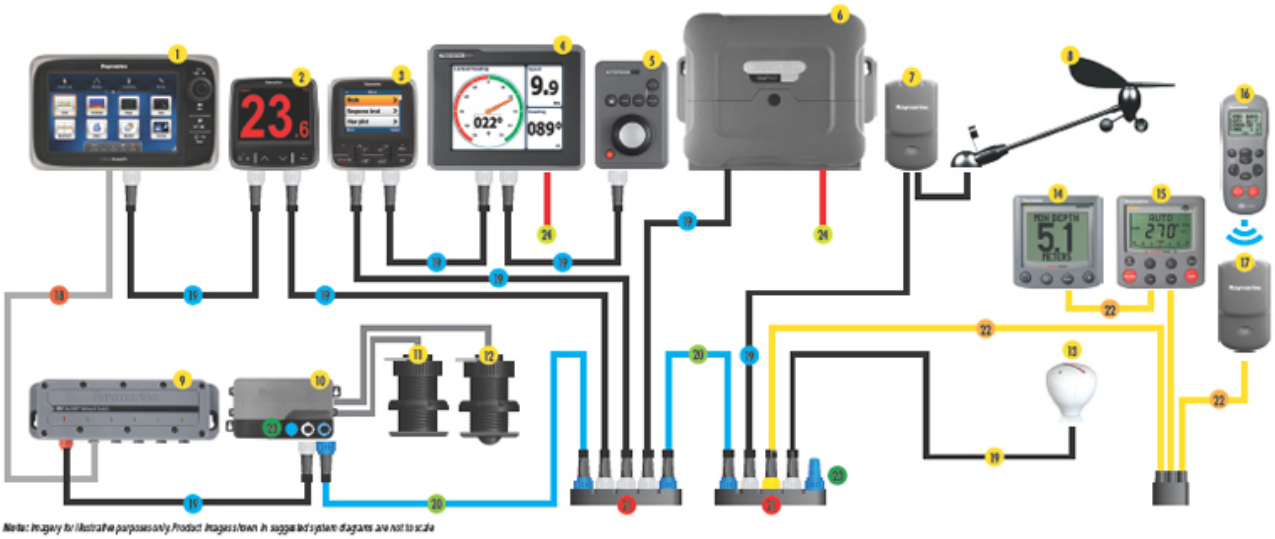
There are a couple things we need to review. The number one item is: What device manufactures are involved. There are 4 principle manufactures we'll talk about:

- RAYMARINE
- GARMIN
- SIMRAD
- FURUNO

These cover 99% about the network configures out there today.

RAYMARINE

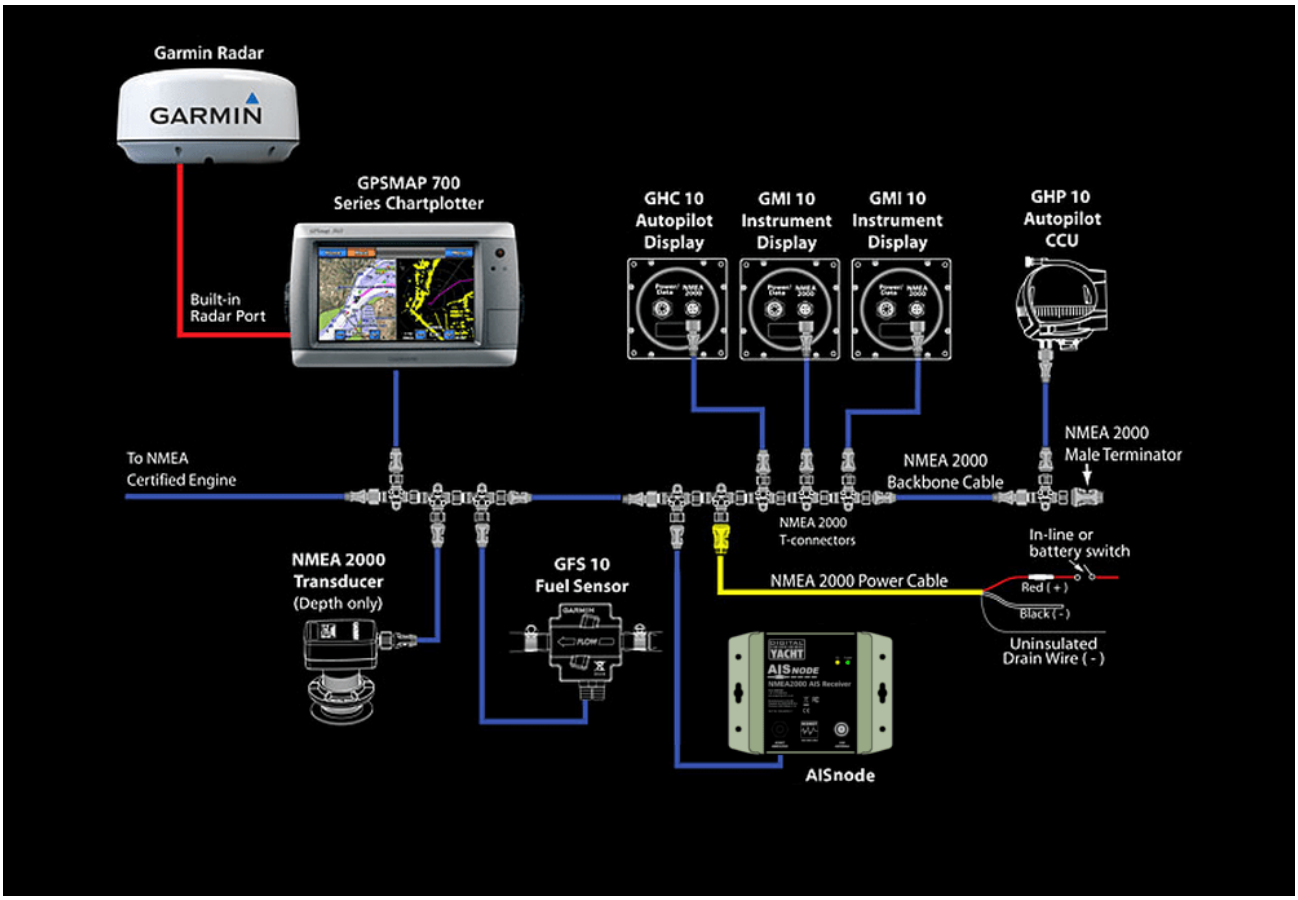
RAYMARINE uses SeaTalk ng as its primary network backbone. From there you can use an adapter cable to connect to a standard NMEA 2000 network.



GARMIN

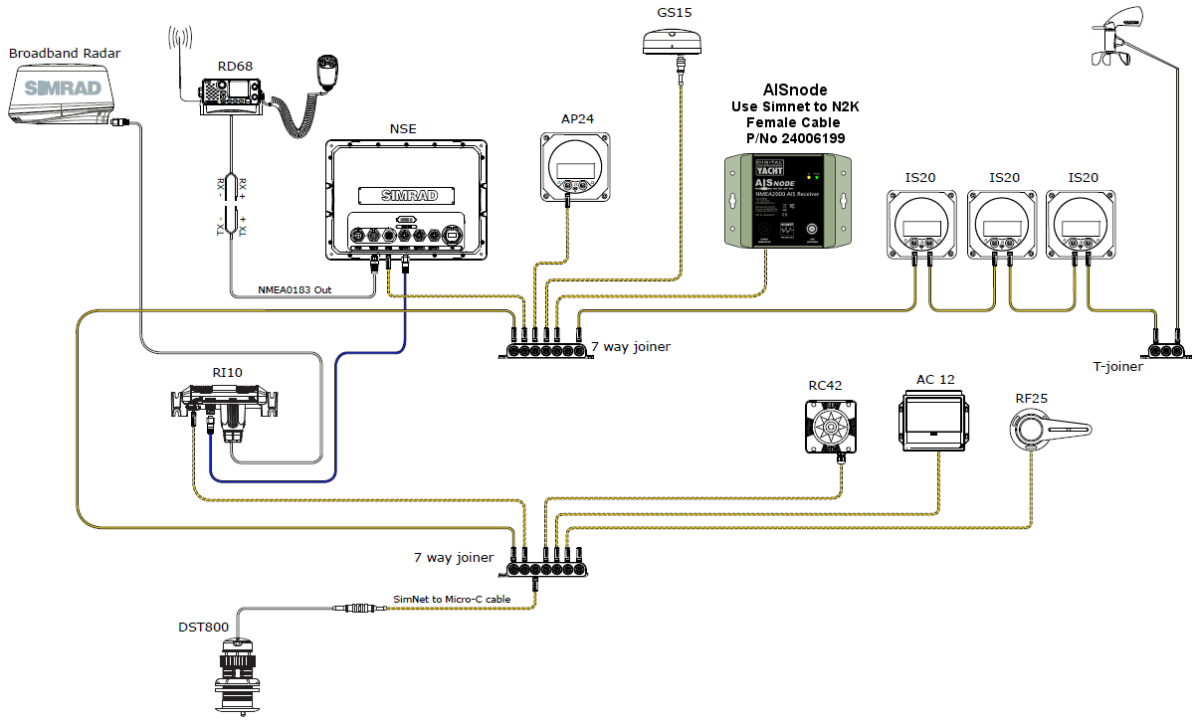
GARMIN uses a standard NMEA 2000 network backbone

Note: Garmin requires a specialized network unit (GMS 10) to connect RADAR to multiple Chartplotters/MFD units.



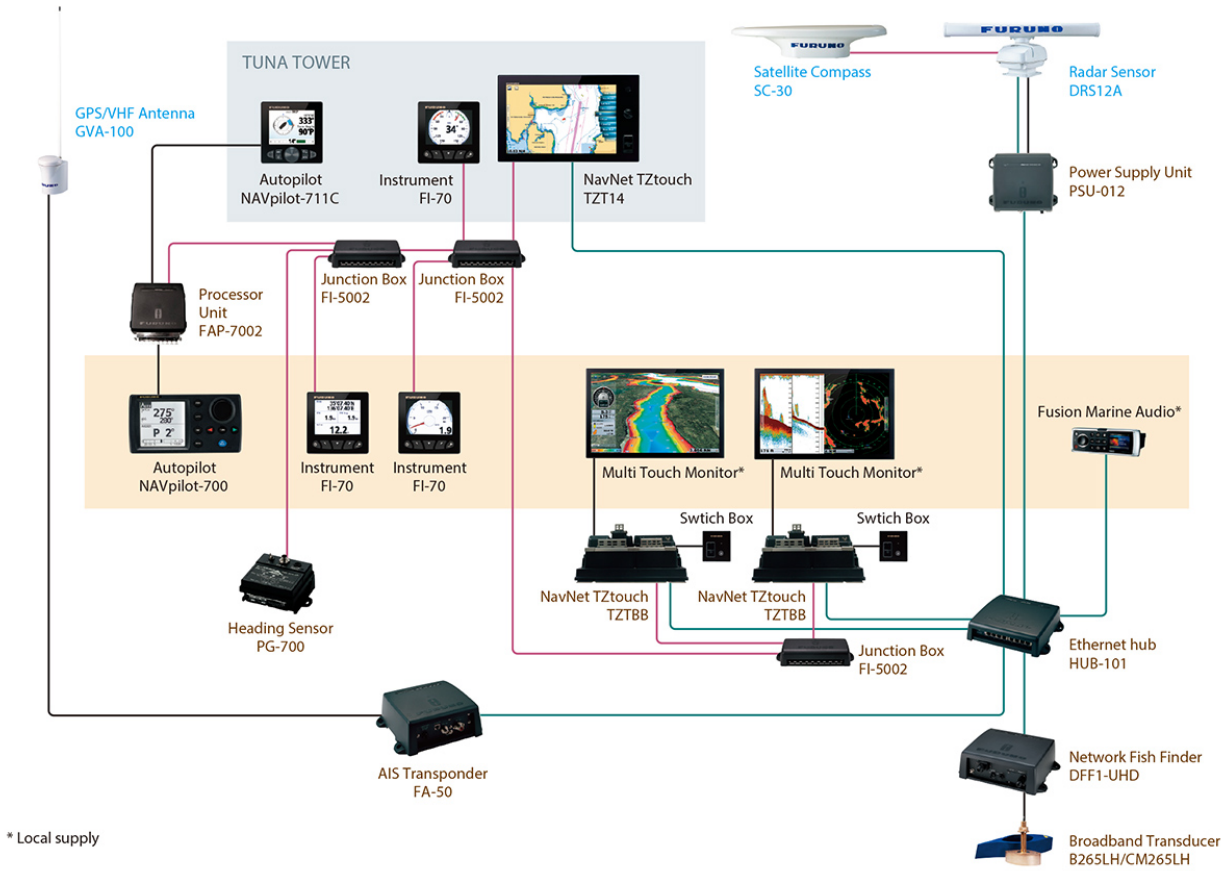
SIMRAD

SIMRAD uses SIMNET a propriety network using serial connections which can be connected to a standard NMEA 2000 network backbone, but requires adapter cables. SIMRAD also requires a specialized unit (SIMRAD Ri10) to feed RADAR data to multiple chart plotters.



FURUNO

FURUNO uses NavNet 3D and NavNet a specialized network that connect to an Ethernet Hub which in turn can use a gateway to connect to a standard NMEA2000 network. NavNet 3D MFD units have one NMEA2000 connector Device Net style connector. You can only connect ONE Furuno MFD to a given NMEA2000 network.



Adding WIFI, Smart Devices and Laptops

Connecting WiFi …The NMEA 2000 Yacht Devices Wi-Fi Gateway allows you to see data from a NMEA 2000 marine digital network on a PC or smartphone.

With it, you get marine network data including vessel course, speed, position, wind speed and direction, water depth, AIS messages from vessels and aircrafts and other navigation data in popular software applications. his unit creates it's own WiFi network and allows you to connect to your NMEA2000 network via WiFi.

This unit WiFi works within about 20 meters , or about 10 meters from down below. You can then download APPs for your pad or smartphone that accepts NMEA2000 data.

This graphic is the EDO app for IPAD. There are lots of apps out there.

Yacht Devices also offers a WiFi gateway, which works the same way offering access of your NMEA2000 data to smartphones and other WiFi devices for use with various Apps.

I also use the Yacht Devices NMEA 2000 to USB adapter for my Laptop computer. This unit connects to the NMEA 2000 backbone and provides a gateway to my laptop for use with various S/W programs available.

On board , on my laptop, I have Garmin Homeport, NAVx, GPSnavX, NavLink, MacENC, and other software programs for navigation. The gateway allows you to see data from a NMEA 2000 marine digital network on a PC, laptop or tablet PC with Microsoft Windows, Mac OS or Linux. With it, you get marine network data including vessel course, speed, position, wind speed and direction, water depth, AIS messages from vessels and aircrafts and other navigation data in PC applications like OpenCPN, Coastal Explorer, Polar View, OpenSkipper, etc.

The device works as a bi-directional gateway so it is also possible to send messages from PC applications to the NMEA 2000 network. That allows, for example, sending of AIS data from a PC USB receiver to a chart plotter, as well as control over the autopilot and the vessel's other equipment. It also supports using a PC as an 0183 to NMEA 2000 converter if you have some NMEA 0183 equipment connected to one of the other PC ports.

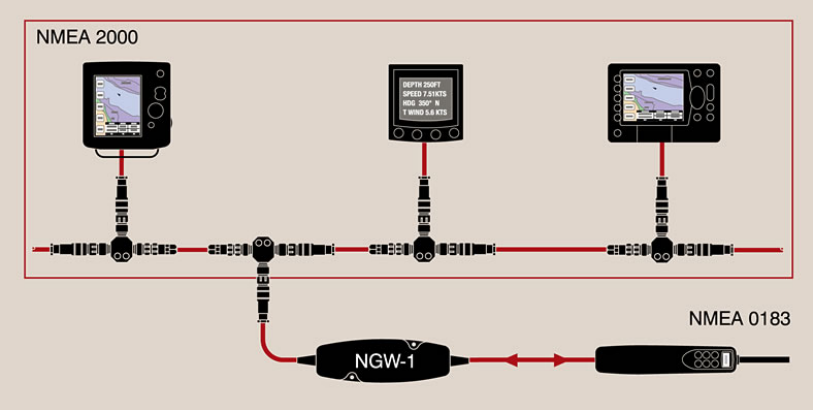
This unit can operate in NMEA0183 mode, NK2 mode, and RAW mode for NMEA2000 traffic.

Keep in Mind that most new Chartplotters/MFDs also offer both WiFi and Bluetooth connections, but tend to provide specific support based on the Manufacturer.

NMEA 2000 to NMEA 0183 Interconnection

Interconnecting an existing NMEA0183 to a new NMEA2000

NMEA 0183 is a low-cost, low-capacity, single-transmitter/multi-receiver network fo interconnecting marine electronic devices, also known as a “single talker/multiple listener” interface. The NMEA 0183 Standard, along with RS-232, RS-422, etc., is often called “Asynchronous Serial” interfaces. This means that data is transmitted serially (bit-by-bit) on a single line. Furthermore, the transmission is asynchronous because no “clock” signal is transmitted with the data.



Due to the difference between the single ended and differential interfaces implemented, older versions of NMEA 0183 prior to version 2.0 cannot be connected to equipment supporting NMEA 0183 version 2.0 or higher without proper interface circuitry.

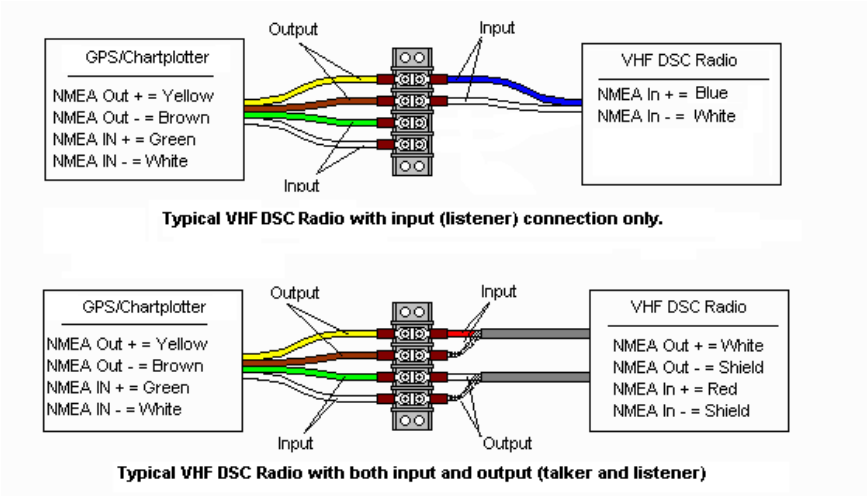
Do not connect one of the signal wires of the differential interface to the common ground of the single ended interface.

We’re going to chat quickly about both

- NMEA 0183 to NMEA 2000
- NMEA 0183 V2.0 to NMEA 2000

The NMEA-0183 standard specifies the talker ports (outputs) and listener ports (inputs) to be differential. This means that the data is transported by means of voltage levels over two wires, separated from ground. Roughly, the voltage levels swing between 0 and 5 Volt, and both wires are in opposite phase. When one is at 5V, the other is 0V and vice versa. Some manufacturer's

though, would not adhere to the standard. It would have been perfect if you could simply connect the 'A' terminal on a talker to the 'A terminal of a listener and do the same with the 'B' terminal. So what came about were these "single ended" connections which complicated matters for the DYI person.



NMEA 0183 originally allowed “single-ended” drive, but was later updated to differential drive (RS-422). RS-232 is a bipolar interface and RS-422 is differential drive. There are four types of connections possible with differential and single ended.

- Differential > Differential
- Single ended > Single ended
- Single ended > Differential
- Differential > Single ended

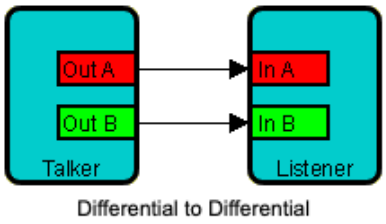
RS-422 is most commonly called “differential drive”. Two wires, A and B are used for this interface, but neither wire is grounded. A “zero” is produced by making A positive with respect to B and a “one” by making B positive with respect to A.

It is therefore the direction of current flow rather than a voltage level that determines the logic state. It is important to note that neither RS-422 signal line (A and B) can be connected to Ground. Both types of outputs will drive opto-isolated listeners.

What is “optp-isolation"

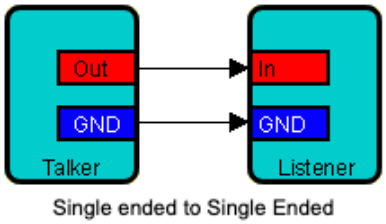
Opto-isolators are actually quite simple devices. They consist of a light source (LED) coupled to a photo transistor. The input data signal turns the LED on and off which causes the photo transistor to switch on and off. The LED and photo transistor are completely isolated from each

other electrically. The data source (talker) must provide sufficient current and voltage to power the LED. A current limiting resistor in series with the LED is generally used for protection. The advantage of opto-isolated inputs is that virtually any type of driver can activate them.

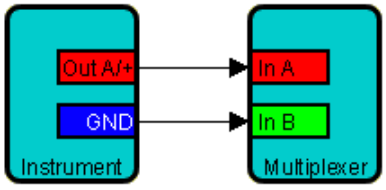


Differential to Differential

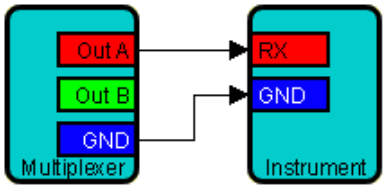
The Actisense NGW-1 NMEA 2000 to NMEA 0183 Gateway is the easiest way to link between a boats old and new data networks. The NGW-1 can convert NMEA 0183 data into NMEA 2000 data and vice-versa.



Single ended to Single Ended



Single ended to Differential



Differential to Single ended

Another alternative is the Amec NK-80 this is another gateway device between NMEA 0183 and NMEA 2000.

The last way works great for people who have an MFD on board. Check the back… you may find that the device has BOTH, a NMEA 2000 and a NMEA 0183 Connection… This can allow both networks to provide data to the MFD.

Comparing NMEA 2000® and NMEA 0183 Sentences

NMEA 2000		NMEA 0183
65280	Heave (Proprietary PGN)	PFEC, GPhve
126992	System Time	RMC, **ZDA**
127245	Rudder	RSA
127250	Vessel Heading129540	HDG, HDM, HDT, RMA, **RMC**, VHW PFEC, GPatt
127251	Rate of Turn	ROT
127257	Attitude	PFEC, GPatt
127258	Magnetic Variation	HDG, RMA, **RMC**
128259	Speed, Water referenced	RMA, **RMC**, VHW, **VTG**
128267	Water Depth	DBT DPT
129025	Position, Rapid Update	GGA, **GLL**, GNS, RMA, **RMC**
129026	COG & SOG, Rapid Update	RMA, RMC, **VTG**
129029	GNSS Position Data	GGA, **GLL**, GNS, RMA
129033	Time & Date	RMC, **ZDA**
129283	Cross Track Error	**APB, RMB, XTE**
129284	Navigation Data	**APB, RMB**, WPL, ZTG
130306	Wind Data	MDA, **MWV**, VWR, VWT
130310	Environmental Parameters	MDA, **MTW**
130311		
129540	GNSS Sats in view	**GSV**
129285	Navigation-Route/WP information	**APB, RMB**, WPL, ZTG
130577	Direction Data	RMA, **RMC**, VHW, **VTG**

Bold: PGNs and sentences whose settings are active at the default setting

Connecting a RAYMARINE SeaTalk 1 to NMEA 2000

My boat , like many other has a SeaTalk 1 network on board when I bought it. It works, it's fine but moving forward I installed all up to date NMEA 2000 systems. In order to bet a SeaTalk 1 network to talk to NMEA 2000, you need to first gateway to SeaTalk ng. This is the kit required to get from SeaTalk 1 to SeaTalk ng. Part Number: E22158 from Raymarine.

Once this is installed you need a Raymarine SeaTalk NG to NMEA 2000 adapter cable. This cable allows you to connect to a T-Connector on your NMEA2000 network. Additional details get rather long winded so i'll save that for another day, or read the manual.

Connecting RAYMARINE SeaTalk 1 to NMEA 0183

Connecting RAYMARINE SeaTalk 1 to NMEA 0183 is a bit more straight forward. You'll want to purchase a Digital Yacht ST-NMEA (ISO) converter.

The SeaTalk™ interface, originally developed by Autohelm in the early 1990's, was included on pretty much all Autohelm and Rarmarine (and some Raytheon) products up until about 2012. As a result there are thousands of boats around the world that have a SeaTalk 1 network. Many of these owners, for one reason or another, need to convert from SeaTalk to NMEA 0183.

Although some of these instruments/MFDs/autopilots have NMEA0183 interfaces, they do not always convert all of the data or are located in a difficult to wire to location.

Digital Yacht's SeaTalk to NMEA 0183 (ISO) converter is a small but powerful interface that provides bi-directional conversion between a SeaTalk network and an NMEA0183 network or device. The ST-NMEA converter takes its power from the SeaTalk network. It features a full, multi-transistor SeaTalk 1 interface, an opto-isolated NMEA0183 input and differential NMEA0183 output. Therefore, key navigational data between the SeaTalk and NMEA0183 networks can be shared reliably.