Connecting hardware to NMEA2000
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1 Introduction

This document is meant for beginners who starts to build their own devices. There is general information, links and hints about building NMEA2000 network on chapter 8 NMEA2000 bus.

Since I published NMEA2000 library I had several times guided beginners with hardware problems. In this document I try to give collected information for recommended and required hardware for making NMEA2000 devices and how to connect them to NMEA2000 bus.

2 Warning

You connect your hardware always with your own risk. I wrote this document to help to connect own hardware to NMEA2000 bus. I do not take any responsible of any errors in document or any possible damages caused to your devices.

3 Some terminology

- Board. Development board like Teensy 3.2, ESP32, Rasberry Pi, Arduino Due etc.
- CAN controller. Is a chip or internal unit of processor, which takes care of CAN (or NMEA2000) bus communication.
- CAN tranceiver (or just tranceiver). “Level shifter” chip between CAN controller Tx/Rx and physical CAN bus CAN-H/CAN-L.
- Termination resistor. 120 ohm resistor on both end of main CAN bus. **Do not forget these!**

4 Recommended hardware

I personally prefer to use Teensy 3.2, 3.5, 3.6, 4.0, 4.1 or ESP32 board. Those boards have internal CAN controller and require only either unisolated MCP2562 or isolated ISO1050 tranceiver for NMEA2000 connection.

With default settings library requires about **23 kB rom and 3.3 kB RAM** in normal operation. So you should have **at least 8 kB RAM** in your processor. If you have Arduino Mega board, it is OK for testing and for small projects, but I do not prefer to buy one for new project. Arduino Due is better, but it is physically bigger and eats more power than Teensies or ESP32. If you have Arduino Uno or any board with less than 8 kB RAM, please read all library issues and Memory requirements on library ReadMe and then forget it. If you anyway want to use it and you have trouble to get it working, please do not set any issues.

4.1 CAN controller

Some boards (or processors) have internal CAN controller. In board there will be simply CAN Tx/CAN Rx pins, which often works with 3.3 V levels. Good examples of this kind of boards are recommended Teensy 3.2, 3.5, 3.6, 4.0, 4.1 or ESP32 boards. Arduino DUE has also internal CAN controller. Never connect CAN Tx/CAN Rx pins directly to NMEA2000 bus.

If you use board without internal CAN controller or you want to have second CAN controller e.g., for Teensy 3.2 or ESP32, you can use external one. Currently only supported is MCP2515. When you search "CAN bus shield" to buy, you have to take care of:

- Library supports only MCP2515 with either 16 MHz or 8 MHz clock. **16 MHz is preferred**.
- Check SPI levels on your board. Most shields operate only with 5 V. If your board I/O is only 3.3 V tolerant, you should find shield with 3.3 V tranceiver. MCP2551 or TJA1050 will not work.

It is relatively easy to solder "CAN bus shield" by self. There is schematics in document ArduinoMega CAN with MCP2515 MCP2551.pdf. If you need to use that with 3.3 V processor, you can replace MCP2551 to MCP2562.

4.2 CAN Tranceiver

CAN controller takes care of CAN (or NMEA2000) bus communication. To connect it to the bus, you need some CAN tranceiver.

4.2.1 Recommended tranceiver

I recommend either unisolated MCP2562 or isolated ISO1050 tranceiver. MCP2562 operates with 5 V and it has own pin to define Tx/Rx logic levels for 3.3 V devices. ISO1050 has own power pin for both sides so it also works with any logic levels.

There is lot of issues with SN65HVD230 tranceiver. If you use that, please do not open issue – it is not library problem.

I do not know why there has been so much problems with SN65HVD230 - according datasheet it should be fine. I have had problems with MCP2562 only twice. Once I mixed Vdd and Vcc - worked fine after connected them right. Another time I connected STBY pin to Vdd, which puts chip to stand by.

4.2.2 Unisolated or isolated tranceiver

This is very important. If you use unisolated tranceiver like MCP2562, you may cause ground loop in your boat. Ground loops may generate other weird problems. You can read more about it e.g., from Ground loop in Wikipedia. If you e.g., feed NMEA2000 bus on center of the boat and you have unisolated device, which also has ground by sensor on front of the boat, you have created ground loop. It may work without problems or may not. You may have communication errors etc.

4.2.3 Unisolated tranceiver

Unisolated tranceiver means that it will share the ground with NMEA2000 bus and with your board. You can use unisolated tranceiver, if you **power your device from NMEA2000** bus and it does not connect to ground from another path like through sensor.

- Devices with onboard temperature, humidity or atmospheric pressure sensors. E.g., device with 1-wire temperature sensor DS18S20 or DHT11 humidity sensor can be made with unisolated tranceiver.
- Devices with other isolated sensors like pressure, ultrasonic, hall effect current etc. Those must get power from your board and their body must be isolated from their ground.
- Devices reading bus and converting data to WiFi.
- Devices with digital input or output as far you use isolation on I/O side. E.g., optoisolators for input and relays for output.

In any case devices with unisolated tranceiver must be powered from NMEA2000 bus and they **can not be connected to unisolated** sensors.

If you program unisolated device through USB connector with laptop, you are in safe when laptop is powered only by batteries. USB will connect your laptop ground to NMEA2000 bus ground, but since laptop is only battery powered, it is “floating” system. If you connect charger to your laptop same time, then it depends of charger do you have ground loop or not. Since this is just temporary connection, it should be OK.

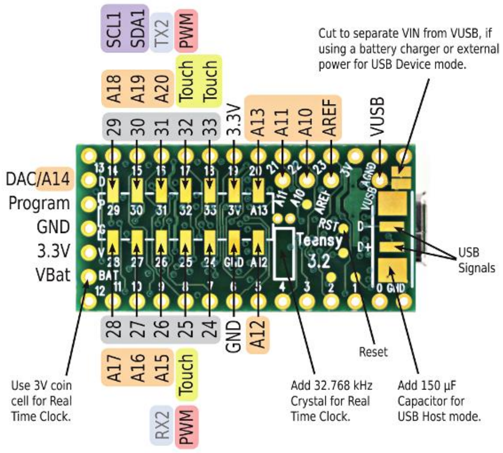
4.2.4 Isolated tranceiver

Isolated tranceiver has either optical or galvanic (ISO1050) isolation. Those has to be powered from both sides with isolated power, so you need also at least two power supplies. You must take care that both sides will also have always separate grounds and they do not touch in any way. Isolated device is safest solution in all cases.

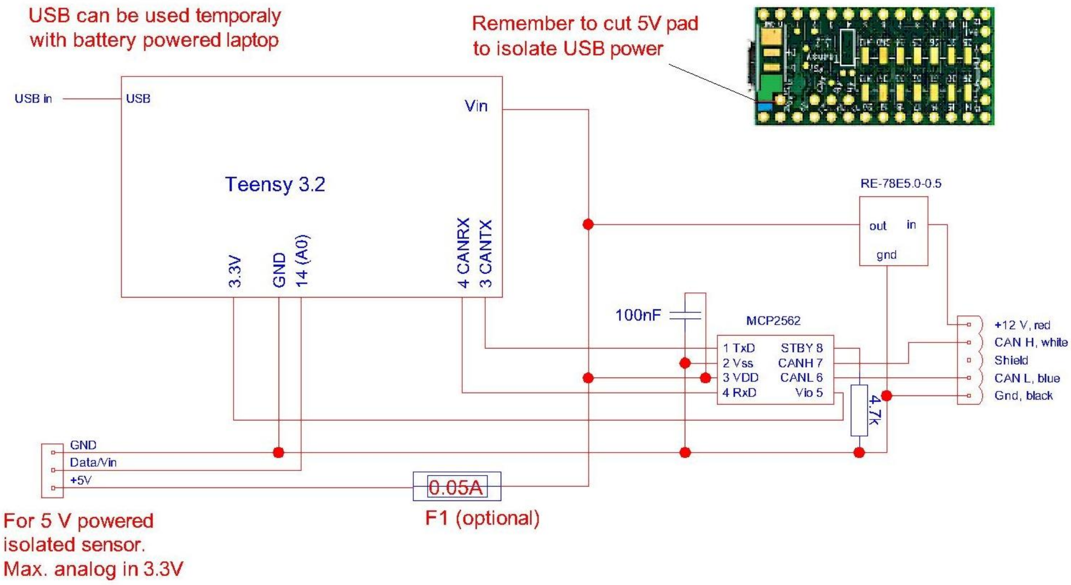
5 Schematics sample

5.1 Feeding power from NMEA2000

Note that development boards have been designed to be powered from USB. If you power your board from NMEA2000, you need to check how you can isolate USB power. All Teensy boards has “5V pad”, which you can cut. E.g., Teensy 3.2

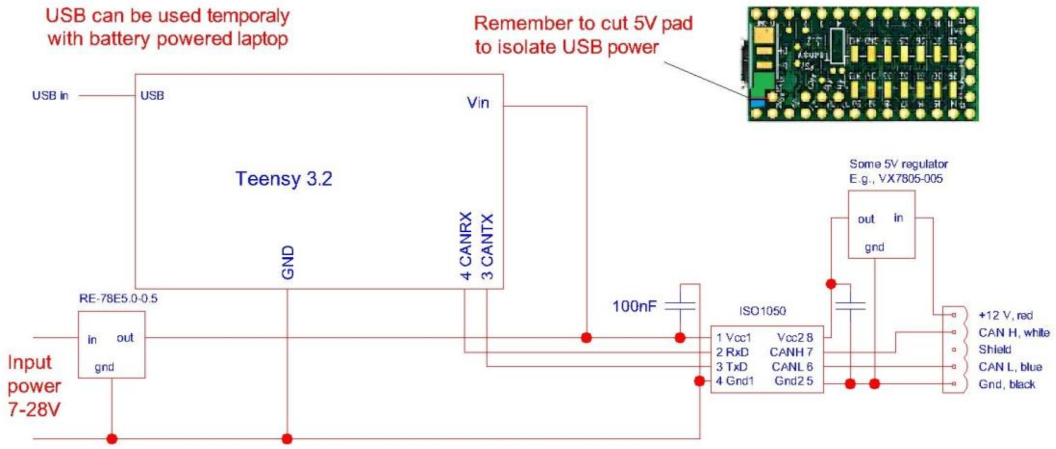

SCL1
SDA1
TX2
PWM
A18
A19
A20
Touch
Touch
29
30
31
32
33
3.3V
A13
A11
A10
AREF
VUSB
Cut to separate VIN from VUSB, if using a battery charger or external power for USB Device mode.
DAC/A14
Program
GND
3.3V
VBat
Teensy 3.2
USB Signals
28
27
26
25
24
GND
A12
A17
A16
A15
Touch
Reset
Use 3V coin cell for Real Time Clock.
Add 32.768 kHz Crystal for Real Time Clock.
Add 150 µF Capacitor for USB Host mode.
RX2
PWM

5.2 Teensy 3.2, simple unisolated



I used this simple schematic at the beginning with 1-wire or other onboard or isolated sensors.

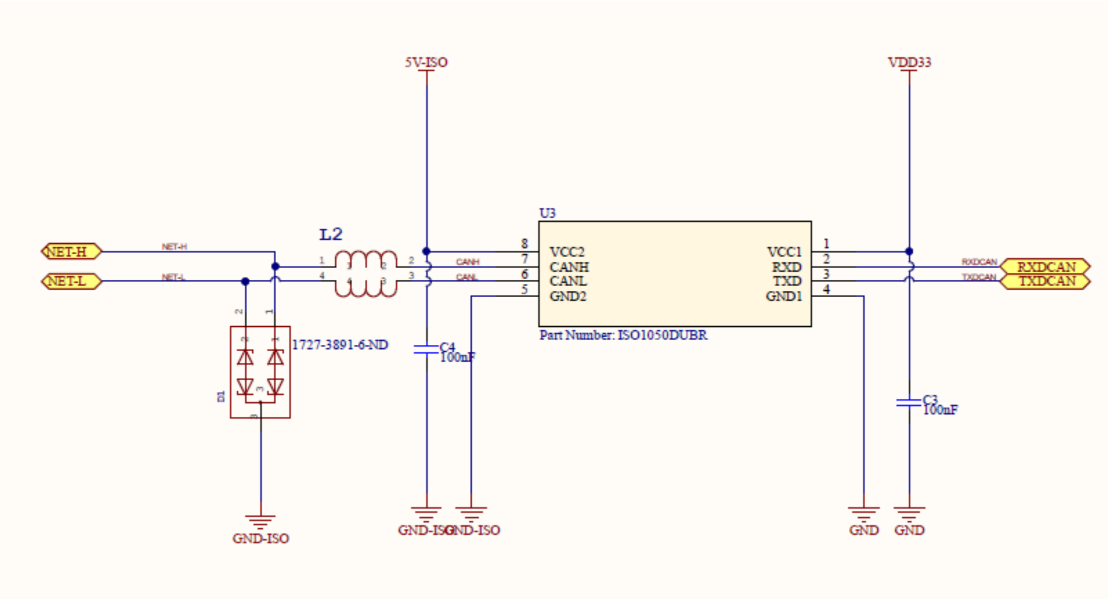
5.3 Teensy 3.2, simple isolated



With isolated tranceiver you are safe to connect different sensors. You can e.g., measure engine temperature from engine by using resistor divider.

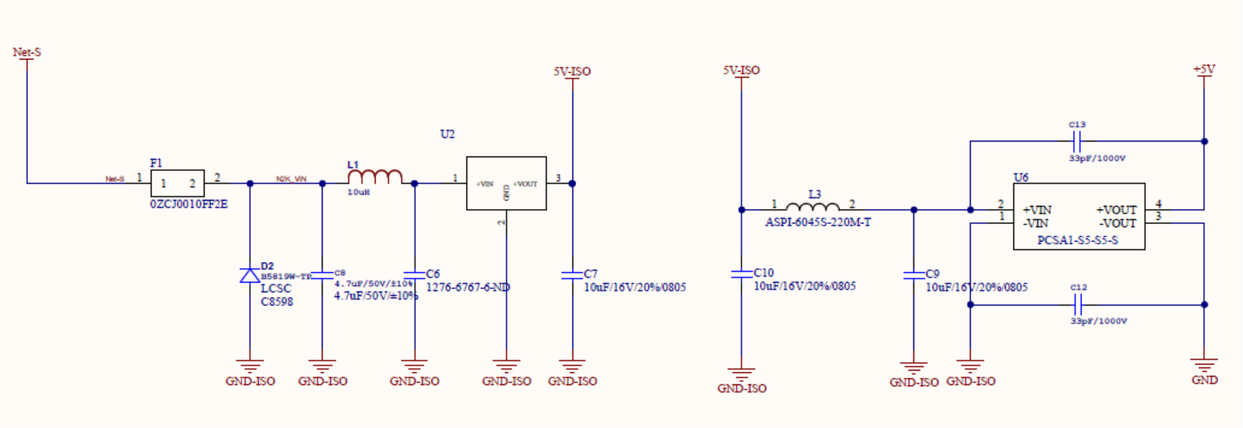
5.4 More protection for tranceiver

Simple samples above did not have any protection to the bus. Unfortunately, power supplies etc. may cause your device to emit noise to the bus – or opposite. To have better protection, you can use something like this.



5.5 Feed isolated power from NMEA2000

If your device does not require much power and you want to feed it totally from NMEA2000 bus, you can use something like this.



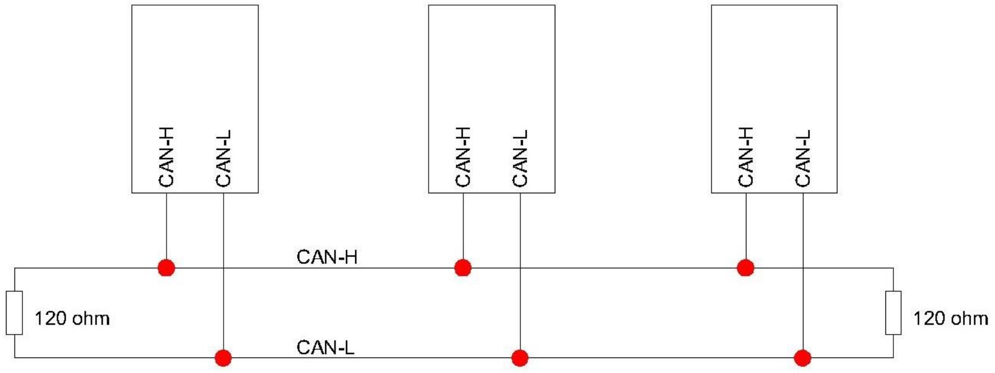
Here Net-S is 12 V and GND-ISO is Gnd from NMEA2000 bus. You then feed your device from +5V/GND. Note that with this connection you do not have isolated 12 V for sensors. If you need that you have to use build your device with separated power supply as in chapter Teensy 3.2, simple isolated.

6 Testing devices

When your device hardware is ready and you have some other device to test it with, you can make simple test bench at home. Simply connect your device NMEA2000 CAN-H/CAN-L with another device. Note that if you use e.g., MFD as other device, that **needs to be powered on NMEA2000 connector** and also with external connector, if it has one. This is because MFD NMEA2000 tranceiver is isolated and powered from NMEA2000 bus.

If you do not have MFD, but have several own devices use example DataDisplay2 on one device to listen bus.

Add 120 ohm termination resistor to both end of your test bus. **The most common problem has been missing or wrong termination resistors!**



Upload e.g., example TemperatureMonitor to your device and run it. It has been tested with Teensy, ESP32, Arduino DUE, Arduino Mega etc. When you run it, you should see it on your MFD device list or whatever your other device is.

If you do not, check at least 10 times your connections, termination resistors, powering. Power off your system and measure that there is 60 ohm resistance between CAN-H and CAN-L. If everything is fine and you use some “CAN bus shield” with MCP2515, check the configuration on software for it is right. Library defaults 16 MHz clock and SPI CS pin 53. In 100% of cases problem has been in hardware or software configuration.

When you have got it working, you can start to develop your own software.

7 Most common hardware errors

If you test your device with e.g., example TemperatureMonitor, it should work. If it start to print “Sent failed” after a while, you will most probably have some hardware failure. “Sent failed” means that your device CAN controller can not send data to the bus. “Sent failed” message will come with delay, when send buffer has been filled up so it depends of your buffer size how long it will take.

- False or unconnected termination resistors. Measure that unpowered NMEA2000 bus has 60 ohm resistance between CAN-h and CAN-L.
- CAN-L/CAN-H mixed
- CAN Rx/Tx mixed.
- Tranceiver broken
- CAN controller broken
- Invalid configuration settings for external CAN controller (MCP2515/mcp_can)
- Invalid CAN Tx/Rx pins connected. (Teensy 3.5, 3.6, 4.0, 4.1)
- Wrong logic levels on tranceiver or external CAN controller (CAN bus shield).
- Isolated receiver like MFD NMEA2000 not powered.
- Tranceiver set to disabled state.

8 NMEA2000 bus

NMEA_2000 bus is electrically CAN bus. NMEA2000 protocol is based on SAE_J1939, with specific messages for the marine environment. The one important thing differing from CAN is that bus speed is fixed to 250kb. On CAN bus it can be up to 1 Mb or even variable. If you are interested, dig more information from internet.

NMEA2000 bus is like ethernet so that you can have multiple devices on same bus, they all can send information to the bus and there is no bus master device. The biggest difference to traditional NMEA0183 connection is that only one device can send data.

8.1 Bus connectors and cables

If you need just one or two cable, it may be easiest to buy it from marine dealer, but if you start to build whole NMEA2000 network, you may save a lot by using industry standard parts.

NMEA2000 bus uses same cabling as DeviceNet, which is used in industry. So you can build your NMEA2000 network with DeviceNet cables and connectors.

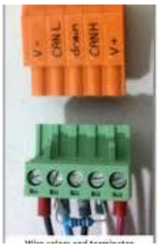
8.1.1 Connectors

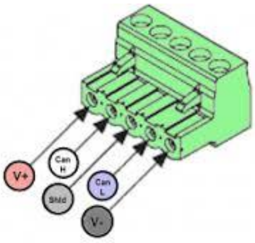
The most common connector used in NMEA2000 is M12 5-pin Micro-C connector.

By searching from internet with ”M12 5-pin Micro-C connector” you will find lot of alternatives cheaper that from local marine dealer. In pictures above are connectors with screw terminals and easy to install. To get smaller sizes you can use connectors with solder terminals.

Note! If you search connector with fixed cable, take care that you select it with DeviceNet colouring.

You can search also “DeviceNet connector” and you will find commonly used connector:



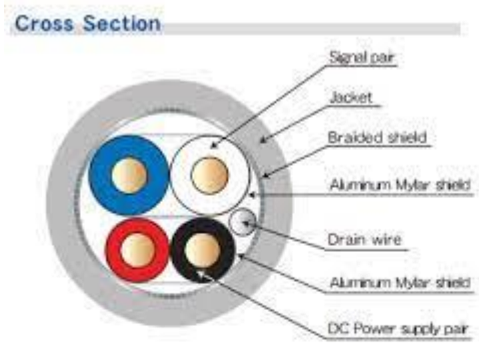


With above model it is easy to make e.g., hub-box instead of using expensive Micro-C hubs.

8.1.2 Cable

In fixed cabling I have used DeviceNet PUR L45467-F16-W8 (1 x 2 x 0,67 mm2 + 1 x 2 x 0,38 mm2). I have used this because it happens to be my cable dealer type. Just google “DeviceNet cable” to find alternatives.

You can use other types of cables, but to make life easier using NMEA2000 or DeviceNet cable you have right pairing, proper shielding and colours: + = red, - = Gnd, CAN-H = white, CAN-L = blue, and shield.



8.2 Bus topology

In NMEA2000 bus there is one main bus called backbone or trunk. Devices to bus will be connected with drop cables. There are lot of good documents available. Look e.g. Proper NMEA 2000 Installation by NMEA organization, Complete guide to building an NMEA2000 network by Actisense, Network Installation guide by Maretron.

Important things are:

- You do not exceed maximum backbone length (100 m for light cable).
- You have one 120 ohm termination resistor on each end of backbone. **If you measure unpowered bus with ohm meter, you should measure 60 ohm resistance between CAN-H and CAN-L**.
- You do not exceed maximum drop cable length, which is 6 m. E.g. in sailing boats, if your bus will go to top of the mast, you have to have that as backbone and so have termination resistor at top of the mast.

- You power bus from exactly one point. This also means that your bus ground wire must be connected ground only on that point to avoid ground loops.

8.3 Prepare for failures

If you had problem on old NMEA0183 connection, only one device went off. With NMEA2000 there is risk that one failing device will lock the whole bus and all your devices will be then off. Simple preparing may safe you from full disaster.

- Make drawing of your NMEA2000 bus connections.
- Make layout drawing of your boat about all NMEA2000 bus connection points so that you can easily locate them. Mark also power feed place.
- Make simple wire with bus connector, which you can use to check bus voltage with volt meter at any connection point.
- Prepare with 1-2 extra termination resistor pieces.
- Make plan, which order you unplug devices from bus in case of failure.

In case you have problems on the bus and it is not clear, simply take drawings and

- Unplug device from some connection point.
- If it does not help, unplug rest of backbone at that point and replace with termination resistor.
- If it does not help, measure voltage on that point.
- If voltage is ok, leave this unconnected and try other connection point.