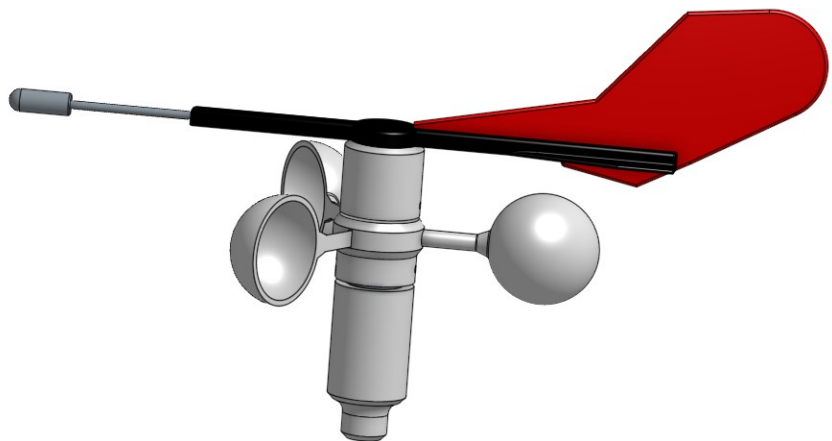


## *Technical Description*

### **Windsensor WiFi 1000**



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# 1 Windsensor WiFi 1000

## 1.1 Preliminary remark

The wind sensor was developed as part of an open source project with the participation of many active sailors of the german sailing forum [www.segeln-forum.de](http://www.segeln-forum.de). The wind sensor is not in direct competition with commercial products. The primary objective was to test the technical possibilities of new technologies such as 3D printing in combination with innovative electronic components such as the ESP8266<sup>6)</sup> and to implement them in a meaningful product. The technical functional principle was taken from the patented wind sensor of Peet Bros and adapted to the technical requirements. The patents<sup>2,3)</sup> have expired, so the functional principle may be used by the general public. It is a safe and simple functional setup requiring just a few components. The Do It Yourself idea was in the foreground. An attempt was made to design a wind sensor which can be assembled by technically interested people themselves, meeting the sailing requirements with regard to function and accuracy. Only components easily available on the market were used. All technical documents and software components have been published so that modifications and improvements can be made at any time.

## 1.2 Description of functions

The wind sensor is a shell anemometer<sup>4)</sup> and is used to measure wind direction and wind speed on boats. Both, wind direction and wind speed are measured by one Hall sensor each.

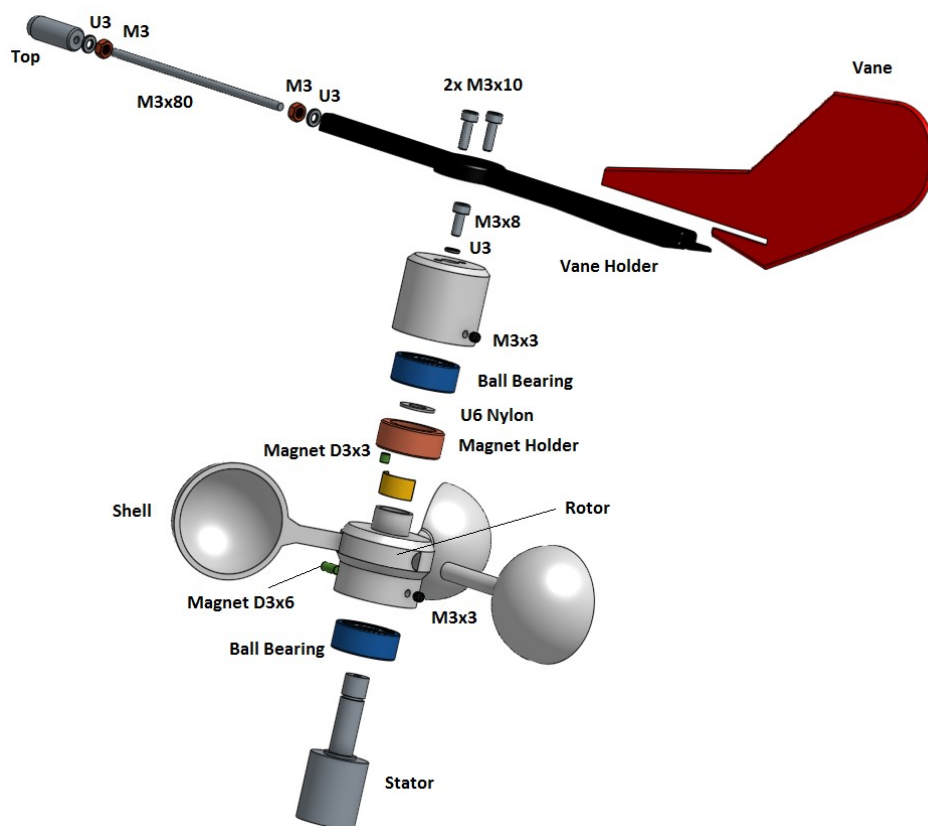
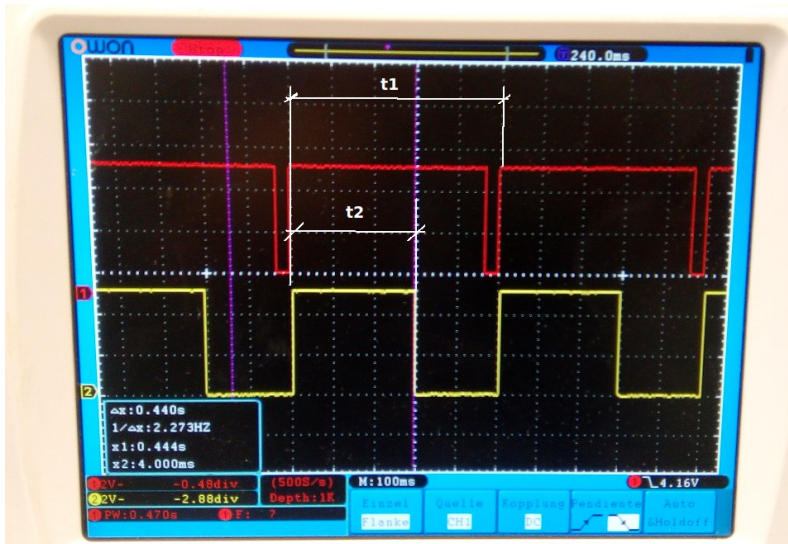


Fig.: Explosion view wind sensor (upper part)

Magnet 1 is mounted on the shell wheel's rotor and circles around the Hall sensor once per revolution, generating a pulse. The circulation time  $t_1$  is determined by interrupt-controlled time measurement. From this the revolution speed  $n$  for the rotor can be calculated. According to theory, the wind speed can be determined via the drag coefficient<sup>5)</sup> of a shell anemometer. The following formula shows the relationship:

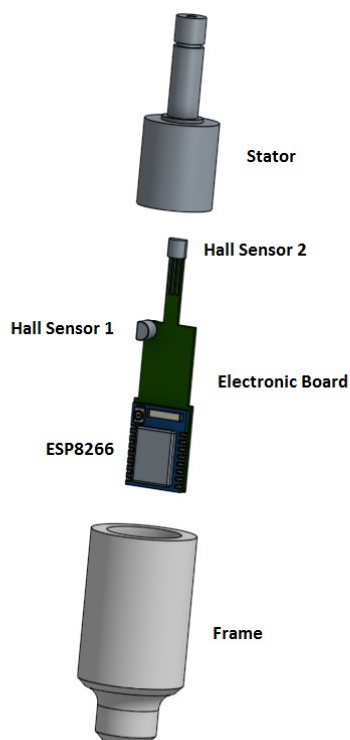
$$\lambda = \frac{u}{v} = \frac{\omega_r \cdot r}{v} = \frac{2\pi n \cdot r}{v}$$

Lamda ( $\lambda$ ) is the drag coefficient and represents a constant that depends on the type of the shell wheel (number and shape of the shells). The number for a typical 3-leaf anemometer is between 0.3 and 0.4. For the wind sensor, the value 0.3 is used. It represents reality fairly accurately. In comparison with a Windmaster 2, both devices agree when this value is used. The friction of the bearings plays almost no role. Knowing the radius  $r$  of the shell wheel, the wind speed  $v$  can be calculated with the help of the rapid running coefficient. The shell anemometer is a resistance runner, since the receding shell slows down the rotational movement. The shell wheel rotates solely due to the different air resistance values of the rear and front side of the shell. The speed only depends on the structure of the shell wheel. The friction of the bearings only determines the wind speed at which the shell wheel begins to rotate (breakaway torque of the ball friction in the bearing). Good devices with sapphire needle suspension start from 0.5 m/s, the wind sensor presented here approximately at 1...1.2 m/s.



**Fig.:** Time signal characteristics of the Hall sensors (red wind speed, yellow wind direction)

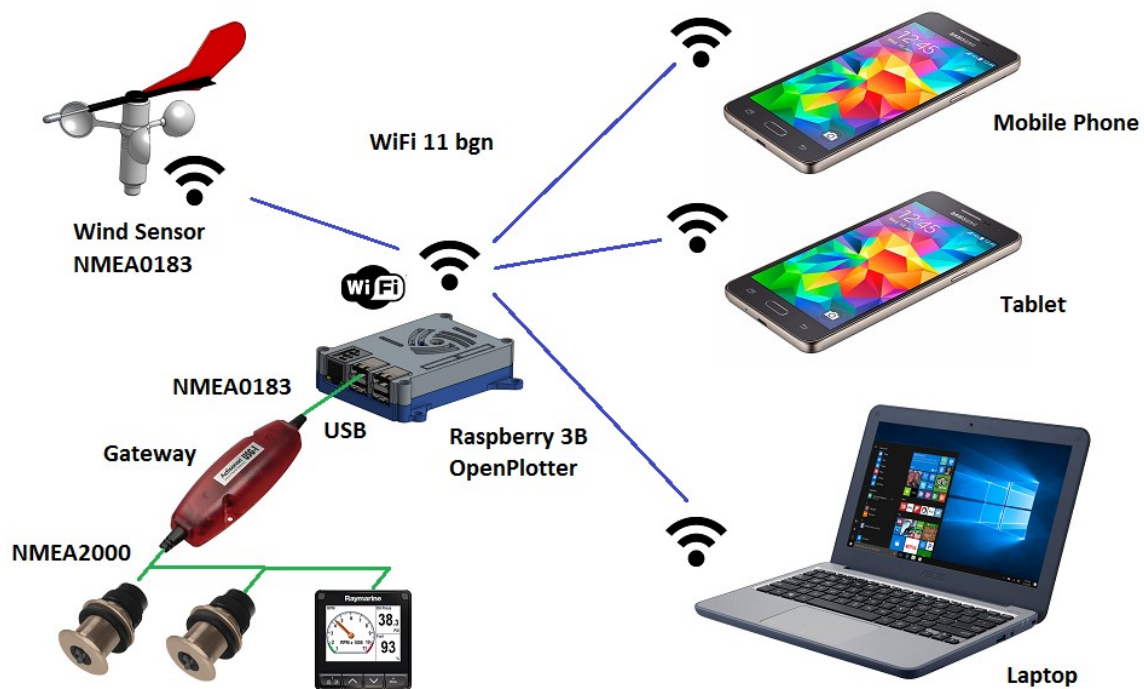
Determination of wind direction is quite smart. According to the patent, and this is the special thing about it, the wind direction is determined with just two digital sensors. Magnet 2 on the wind vane aligns itself according to wind direction and the rotating shell wheel leads a magnetic diaphragm past the wind vane magnet shielding the magnetic field of Hall sensor 2 for wind direction measurement. The wind direction can be calculated over time span  $t_2$ . The time  $t_2$  varies between 0 and  $t_1$  depending on wind direction. However, this also means that the wind direction can only be determined when the shell wheel rotates. This is of no further concern, because the wind direction is not relevant if there is no wind. The only shortcome is that (with wind speed increasing), the accuracy of the wind direction determination will decrease, since less time is available to determine the time of  $t_1$  and  $t_2$  with timer ticks. ESP8266 just provides a millisecond timer, which increments a counter every millisecond to determine the time of  $t_1$  and  $t_2$  in ms. At wind force 12 bft (140km/h) the shell wheel rotates at about 1800 rpm. That leaves only 30 ms (or 30 counts) to determine the time per revolution. This decreases accuracy of the time determination of  $t_1$  and  $t_2$ . The operating parameters table shown in the appendix illustrate this relationship. However this effect may be considered less significant, since increasing wind force will decrease the need for super accurate wind direction readings.



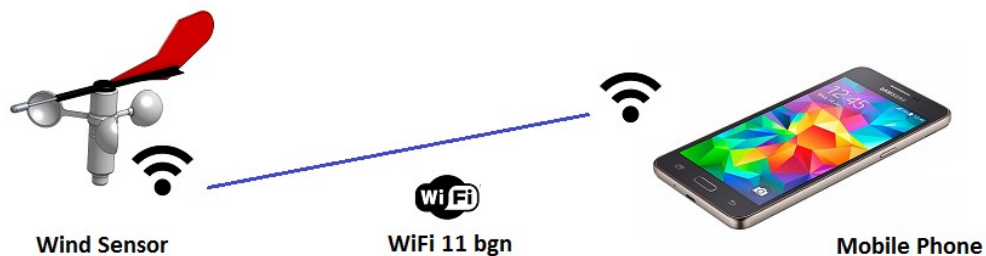
**Fig.:** Explosion view wind sensor (lower part)

There is a circuit board in the stator for signal evaluation. The board contains the Hall sensors, the mini embedded module ESP8266<sup>6)</sup>, the control electronics and the power supply. The Hall sensors generate digital signals as the magnets pass by. These are detected and evaluated by the ESP8266. The ESP8266 is a highly-miniaturized minicomputer with WLAN module that can be programmed in C and other programming languages. In the Arduino development environment<sup>8)</sup>, all components for the ESP8266 are already integrated, so a large number of software libraries can be conveniently accessed for programming. The board is compatible with the Wemos D1 mini<sup>7)</sup> embedded module and has the programming logic already integrated on the board. With a serial USB converter for 3.3V logic level, the ESP8266 can be easily programmed via the Aduino IDE. The board provides 6 connectors for programming and power supply.

The wind sensor can automatically send wind data to an existing WLAN network and act as a permanent member of the network. If application software such as OpenPlotter<sup>14)</sup> is active in the same network, the wind sensor measurement data can be read and displayed by OpenPlotter. The main data protocol used is NMEA0183<sup>10)</sup>. However, other protocols are also available. Basically, any software like OpenCPN<sup>15)</sup>, AvNav<sup>16)</sup> and others can be used for data evaluation as long as it can read and process NMEA0183 data records via network (see Appendix: Software Compatibility List). Please note that only one network participant can be connected to the wind sensor at a time. Multiple connections to the wind sensor are not possible. However, OpenPlotter can be used to output the wind sensor data to multiple participants at the same time.

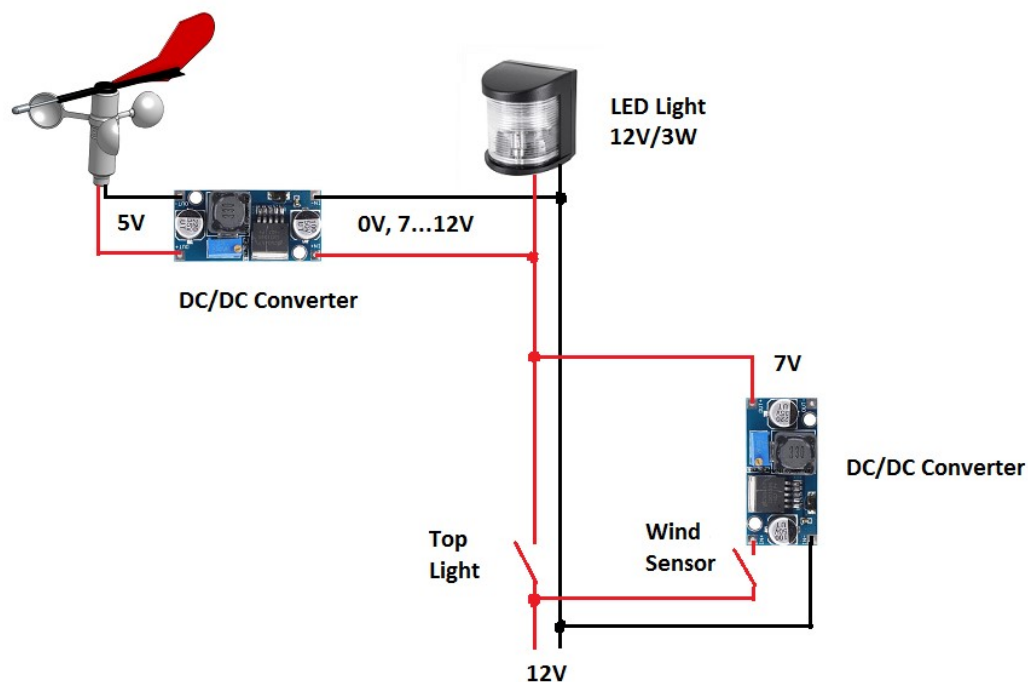


**Fig.:** Connection options with OpenPlotter as central data server and several end devices (Point to Multipoint)



**Fig.:** Direct connection between wind sensor and terminal (point-to-point)

To parameterize the wind sensor, an access point is provided by the wind sensor, which sets up its own independent network. Parameterization as well as software updates can be applied via a web interface.



**Fig.:** Power supply via the top light in the mast

Power supply of the wind sensor does not require a separate cable in the mast. You can take the power from the top light to supply the wind sensor. By means of a step down DC/DC converter, the sensor operates in the range between 7V...12V. If a LED bulb serves as top light, a reduced input voltage of ~7V can be used to ensure that just the wind sensor is powered on while the LED lamp remains unlit. If you want both to work, you just have to apply a voltage of 12V. So the wind sensor can be installed in existing systems without major conversions and extensions.



### 1.3 Technical Data

Designation	Value / Range of values	Comment
Wind speed	0...40 m/s, 0...78 kn	
Start wind speed	1 m/s	
Wind direction	0...360°	
Resol. wind direction	0.3...6° at 0...40kn	
Type of function	magnetic, Hall sensor	
Ambient temperature	0...60°C	
Storage temperature	-10...80°C	
Air Humidity	0...100%	
Power supply	5V	reversed polarity protection
Consumption	1W	typical
Data transmission	WiFi 11 bgn	
Data rate	3 Mbit	
Range	app. 50 m	free field
Data protocols	NMEA0183 WiFi	
	NMEA0183 serial	3,3V logic level
	JSON WiFi	data transmission
	HTTP Access Point	for parameter settings
	TCP Socket	data connection
NMEA0183 Data types	MWV	details see appendix
	VWR	
	VPW	
	INF	custom Code
Tightness class	IP63	protected against spray water
Dimensions L x W x H	295 x 180 x 170 mm	without tube and base
Weight	275 g	including tube and base
	165 g	without tube and base
Plastic	PLA: enclosure parts	painted
Metal	Alu: stator, tube, base	seawater resistant
	V4A: tip, threaded rod	
	V4A: screws, nuts	
Approvals	none	
Warranty	none	
Licenses	CC-BY-NC-SA	hardware
	OpenSource, GPL 3.0	software

## 1.4 Installation and safety instructions

The wind sensor should be mounted on the mast so that there is sufficient distance to other components such as position lights, antennas or similar. Otherwise wind turbulences may occur and the measurement results may be compromised. Wind direction measurement is particularly affected by this. Basically, the wind sensor should be installed vertically on sufficiently dimensioned mounts. Due to swell and position, large forces can be transmitted to the wind sensor. Especially at high wind speeds, large torques and moments of inertia can occur at the rotor which are transmitted to the mounting foot.

### Notes



Ensure that the wind sensor is perpendicular to the mast.

Dismantle the wind vane and shell wheel before mounting in order to avoid damage.

Assure the screws are properly tightened and secured against accidental loosening with threadlocking fluid.

There must be an electrical protector for overload (fuse) in the wind sensor supply line.

Protect electrical connections against moisture and provide a strain relief so that the dead weight of the cables in the mast is not transferred to the connecting cables.

Rust film can adhere to the magnets and impair the mobility of the components. The measured values may then be compromised.

If possible, protect the vane and shell wheel from frost and remove them before winter storage.

If the ship is heeling, the wind direction readings may be compromised.

### Warning



***The wind sensor is only a technical aid and must not be used in safety-critical areas. When coupled with autopilots, there is a risk of life and limb due to malfunctions. No liability is accepted for direct or indirect damage. The skipper must have the ability to control the ship at all times, even if the wind sensor fails.***

In the event of collisions with the wind sensor, the device must be taken out of operation and inspected for damage. If necessary, damaged parts must be replaced. Only then it may be put back to operation.

The supply voltage of the wind sensor (at pins 1 and 6) must not exceed 6V. The sensor can be thermally destroyed during prolonged operation at 12V. Therefore, never connect the sensor directly to the 12V on-board power supply. A DC/DC converter must always be connected upstream.

Check the condition of all components of the wind sensor for damage at regular intervals, especially the plastic parts exposed to UV radiation. Immediately replace fragile plastic parts with new ones. There is a danger of falling components.

Do not overtighten the M10 screw on the mounting foot. There is a risk that the thread will break off.

## 1.5 Maintenance

The wind sensor does not require any special maintenance during operation. The sensor should be inspected at regular intervals. For this purpose, the wind vane and the shell wheel are removed and checked for impurities. In particular, flash rust can accumulate on the magnets and must be removed. The ball bearings must be checked for smooth running and low clearance. If necessary, the bearings can be cleaned with alcohol and lubricated with silicone oil. Brittle and cracked plastic parts must be replaced.

## 1.6 Disposal



At the end of its lifetime, the wind sensor can be dismantled into individual parts and sorted according to materials. The plastic and metal parts can be disposed of via the Dual Domestic Waste Disposal System.



The electronic circuit board must not be disposed of in the household waste and must be handed over to the local disposal company.

## 1.7 Licenses



The technical descriptions, schematics, design drawings and 3D models of the wind sensor called Works are subject to the Creative Commons (CC) License by-nc-sa. All works may be reproduced and modified for non-commercial purposes provided that the author is acknowledged. Derived works are subject to the same license and may not be otherwise licensed.



The software of the wind sensor is subject to GPLv3. The software is open source and can be duplicated, modified and distributed by anyone. The derived works are also subject to GPLv3. The full text of GPLv3 can be read in detail under at <https://www.gnu.org/licenses/gpl-3.0.en.html>

## 1.8 Disclaimer of liability

The entire construction of the wind sensor was carried out with great care and technical expertise. Under certain circumstances however the construction may not function properly. No liability can be accepted for damage, recourse or legal claims arising from this. A guarantee on functional safety is not given. The wind sensor is used by the user as it is.

## 2 Appendix

### 2.1 Operating parameters

v	v	v	v	n	t	Angle
[m/s]	[kn]	[bft]	[km/h]	[1/s]	[ms]	Resolution
[°]						
0	0.0	0.0	0.0	0.0		
1	1.9	0.7	3.6	0.8	1256.6	0.3
2	3.9	1.3	7.2	1.6	628.3	0.6
3	5.8	1.8	10.8	2.4	418.9	0.9
4	7.8	2.3	14.4	3.2	314.2	1.1
5	9.7	2.7	18.0	4.0	251.3	1.4
6	11.7	3.2	21.6	4.8	209.4	1.7
7	13.6	3.6	25.2	5.6	179.5	2.0
8	15.6	4.0	28.8	6.4	157.1	2.3
9	17.5	4.4	32.4	7.2	139.6	2.6
10	19.4	4.8	36.0	8.0	125.7	2.9
11	21.4	5.2	39.6	8.8	114.2	3.2
12	23.3	5.5	43.2	9.5	104.7	3.4
13	25.3	5.9	46.8	10.3	96.7	3.7
14	27.2	6.2	50.4	11.1	89.8	4.0
15	29.2	6.5	54.0	11.9	83.8	4.3
16	31.1	6.8	57.6	12.7	78.5	4.6
17	33.0	7.1	61.2	13.5	73.9	4.9
18	35.0	7.4	64.8	14.3	69.8	5.2
19	36.9	7.6	68.4	15.1	66.1	5.4
20	38.9	7.9	72.0	15.9	62.8	5.7
21	40.8	8.1	75.6	16.7	59.8	6.0
22	42.8	8.4	79.2	17.5	57.1	6.3
23	44.7	8.6	82.8	18.3	54.6	6.6
24	46.7	8.9	86.4	19.1	52.4	6.9
25	48.6	9.1	90.0	19.9	50.3	7.2
26	50.5	9.4	93.6	20.7	48.3	7.4
27	52.5	9.6	97.2	21.5	46.5	7.7
28	54.4	9.8	100.8	22.3	44.9	8.0
29	56.4	10.1	104.4	23.1	43.3	8.3
30	58.3	10.3	108.0	23.9	41.9	8.6
31	60.3	10.6	111.6	24.7	40.5	8.9
32	62.2	10.8	115.2	25.5	39.3	9.2
33	64.1	11.1	118.8	26.3	38.1	9.5
34	66.1	11.4	122.4	27.1	37.0	9.7
35	68.0	11.6	126.0	27.9	35.9	10.0
36	70.0	11.9	129.6	28.6	34.9	10.3
37	71.9	12.2	133.2	29.4	34.0	10.6
38	73.9	12.5	136.8	30.2	33.1	10.9
39	75.8	12.8	140.4	31.0	32.2	11.2
40	77.8	13.1	144.0	31.8	31.4	11.5

## 2.2 Description NMEA data telegrams

### MWV – Wind speed and wind direction

```

      1  2 3 4 5 6
      |  | | | |
$--MWV,x.x,a,x.x,a*hh<CR><LF>

```

Field Number:

- 1) Wind direction, 0...360°
- 2) Type, R = Apparant wind, T = True wind
- 3) Wind speed
- 4) Unit wind speed, K/M/N
- 5) Status, A = Data valid
- 6) Checksum

### VWR - Apperant wind direction and wind speed

```

      1 2  3 4  5 6  7 8 9
      | |  | |  | |  | |
$--VWR,x.x,a,x.x,N,x.x,M,x.x,K*hh<CR><LF>

```

Field Number:

- 1) Wind direction 0...180°
- 2) Wind direction left (L) / right (R)
- 3) Wind speed in kn
- 4) N = Unit knots
- 5) Wind speed in m/s
- 6) M = Unit m/s
- 7) Wind speed in km/h
- 8) K = Unit km/h
- 9) Checksum

### VPW – Wind speed – measured parallel to wind

```

      1 2 3 4 5
      | | | | |
$--VPW,x.x,N,x.x,M*hh<CR><LF>

```

Field Number:

- 1) Wind speed in kn, "-" means downwind
- 2) N = Unit knots
- 3) Wind speed in m/s, "-" means downwind
- 4) M = Unit m/s
- 5) Checksum

**INF – Wind speed and wind direction (Custom Code)**

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

**\$--INF,0,x.x,D,x.x,D,x.x,M,x.x,K,x.x,N,x.x,B,A\*hh<CR><LF>**

Field Number:

- 1) Sensor number
- 2) Wind direction in 0...360°
- 3) D = Unit degree
- 4) Wind direction resolution in °
- 5) D = Unit degree
- 6) Wind speed in m/s
- 7) M = Unit m/s
- 8) Windspeed in km/h
- 9) K = Unit km/h
- 10) Wind speed in kn
- 11) N = Unit kn
- 12) Wind Speed in bft
- 13) B = Unit bft
- 14) Status, A = valid
- 15) Checksum

**2.3 Software Compatibility List**

Application Software	Connection	Operating Sytem	Comment
OpenPlotter	WiFi, serial, NMEA0183	Linux, Raspi	can be used as gateway for other data networks
OpenCPN	WiFi, serial, NMEA0183	Linux, Windows, Mac, Android, Raspi	universal
AvNav	WiFi, NMEA0183	Linux, Android, Raspi	
Navionics	WiFi, NMEA0183	Android	only one connection possible
NvCharts	WiFi, NMEA0183	Android	only one connection possible
WinGPS Marine	WiFi, NMEA0183	Android, Windows	Full version, only one connection possible
Vaarkart Friese Meren	WiFi, NMEA0183	Android	Full version, only one connection possible
DKW Kartensoftware	WiFi, NMEA0183	Android	Full version, only one connection possible

## 2.4 Additional Information

- 1) Segelforum: <https://www.segeln-forum.de>
- 2) Peet Bros US-Patent: <https://patents.google.com/patent/US5231876A/en>
- 3) Peet Pros EU-Patent: <https://patents.google.com/patent/EP0514184A2/en>
- 4) Anemometer basics: <https://en.wikipedia.org/wiki/Anemometer>
- 5) Drag Coefficient: [https://en.wikipedia.org/wiki/Drag\\_coefficient](https://en.wikipedia.org/wiki/Drag_coefficient)
- 6) ESP8266: <https://en.wikipedia.org/wiki/ESP8266>
- 7) Wemos D1 mini: [https://docs.wemos.cc/en/latest/d1/d1\\_mini.html](https://docs.wemos.cc/en/latest/d1/d1_mini.html)
- 8) Arduino IDE: <https://www.arduino.cc/en/Main/Software?>
- 9) Raspberry Pi: <https://www.raspberrypi.org/>
- 10) NMEA0183 data telegrams: <http://www.nmea.de/nmea0183datensaetze.html>
- 11) 3D Online CAD System Onshape: <https://www.onshape.com/>
- 12) Creative Commons Lizenz: <https://creativecommons.org/licenses/?lang=en>
- 13) GPLv3: <https://www.gnu.org/licenses/quick-guide-gplv3.en.html>
- 14) OpenPlotter: <https://openmarine.net/openplotter>
- 15) OpenCPN: <https://opencpn.org/>
- 16) AvNav: <http://www.wellenvogel.net/software/avnav/index.php>