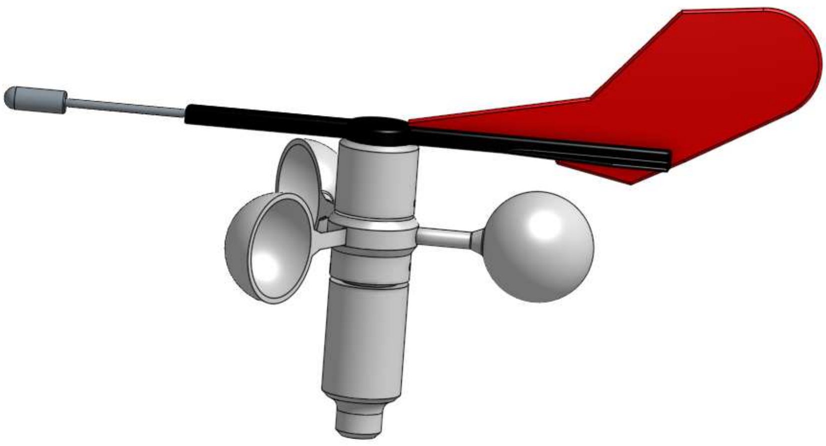
Technical Description

Windsensor WiFi 1000



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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 sail form 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 [6)] 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. Patent [2,3)] has currently expired, so that the functional principle may be used by the general public. It is a safe and simple functional principle that requires only 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 and which meets the sailing requirements with regard to function and accuracy. Only components 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 [4)] and is used to measure the wind direction and wind speed on boats. Both the wind direction and the wind speed are measured with one Hall sensor each.

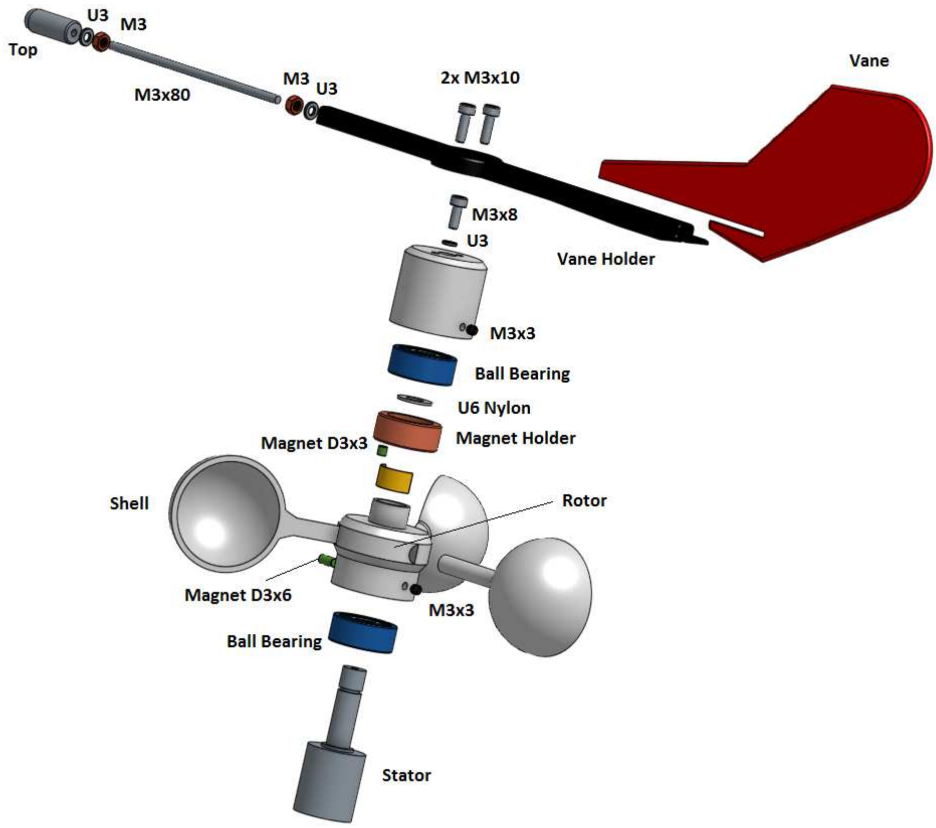

Fig.: Explosion view wind sensor (upper part)

The magnet 1 is located on the rotor of the shell wheel and runs along the Hall sensor 1 per revolution, generating a pulse. The circulation time t_1 is determined via an interrupt-controlled time measurement. From this, the speed n for the rotor can be calculated. According to theory, the wind speed can be determined via the drag coefficient 5) of a shell anemometer. The following formula shows the relationship.

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

Lamda (λ) 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.

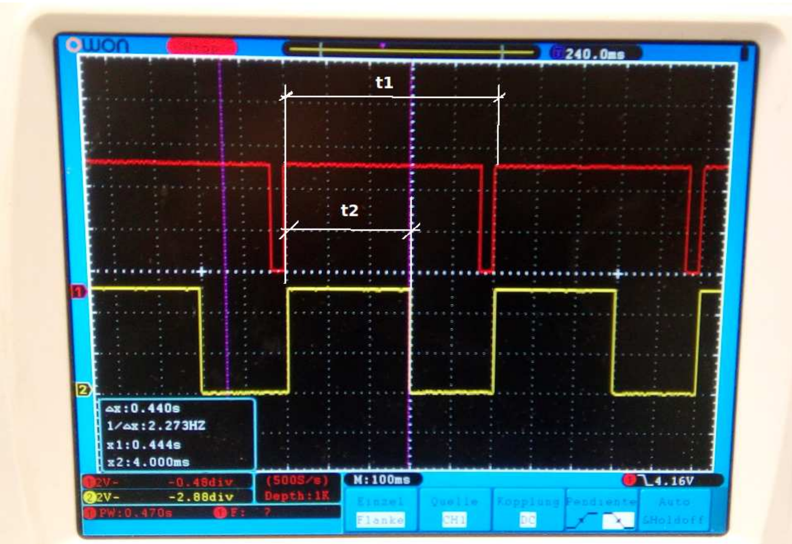

Fig.: Time signal characteristics of the Hall sensors (red wind speed, yellow wind direction)

The wind direction is determined very tricky. According to the patent, and this is the special thing about it, the wind direction is only determined with two digital sensors. The 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 and interrupts the magnetic field of the Hall sensor 2 for wind direction measurement. The wind direction can be calculated over the time span t_2. The time t_2 then varies between 0 and t_1 depending on the wind direction. However, this also means that the wind direction can only be determined when the shell wheel rotates. But this is not further tragic, because the wind direction is of no interest if the wind is not blowing. The only unpleasant thing is that as the wind speed increases, the accuracy of the wind direction determination decreases, since less time is available to determine the time of t_1 and t_2 with timer ticks. In ESP8266 there is only one millisecond timer, which increases a counter every millisecond and determines the time of t1 and t2 in ms. At wind force 12 bft (140km/h) the shell wheel rotates at about 30 rpm. That leaves only 30 ms or 30 counts to determine the time for one revolution. This makes the time determination of t_1 and t_2 less accurate. The operating parameters table in the appendix shows this relationship. However, this effect is not so tragic, since with increasing wind force it is no longer so interesting where the wind is blowing exactly from.

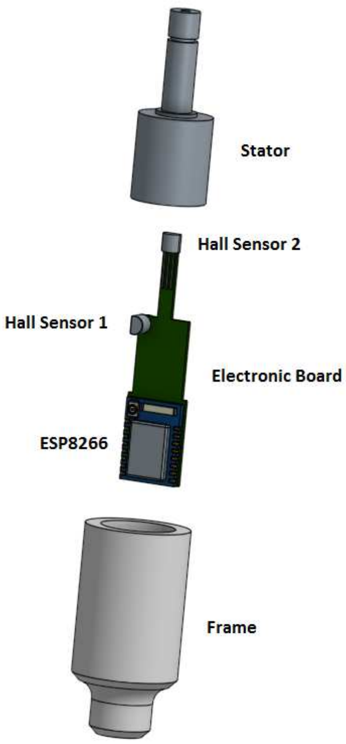

Fig.: Explosion view wind sensor (lower part)

There is a circuit board in the stator for signal evaluation. The board contains the Hall sensors, the mini embedded module ESP8266 6), the control electronics and the power supply. The Hall sensors generate digital signals as the magnets pass by and 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 8), all components for the ESP8266 are already integrated, so that a large number of software libraries can be conveniently accessed for programming. The board is compatible with the Wemos D1 mini 7) 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 Adruino IDE. The board has 6 connectors for programming and power supply.

The wind sensor can automatically wind data write into an existing WLAN network and is then a permanent member of the network. If application software such as OpenPlotter 14) 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 10). However, other protocols are also available. Basically, any other software e.g. AvNav 16) 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 several participants at the same time. Thus, commercial sensors can also be integrated if an NMEA2000/NMEA0183 gateway such as Actisense NGW-1 is used. The data of both network systems are exchanged via the gateway. The sensor data of the NMEA200 network can also be evaluated and displayed in OpenPlotter. Likewise, data from OpenPlotter can be fed into the NMEA2000 network and the data can be displayed via the on-board instruments.

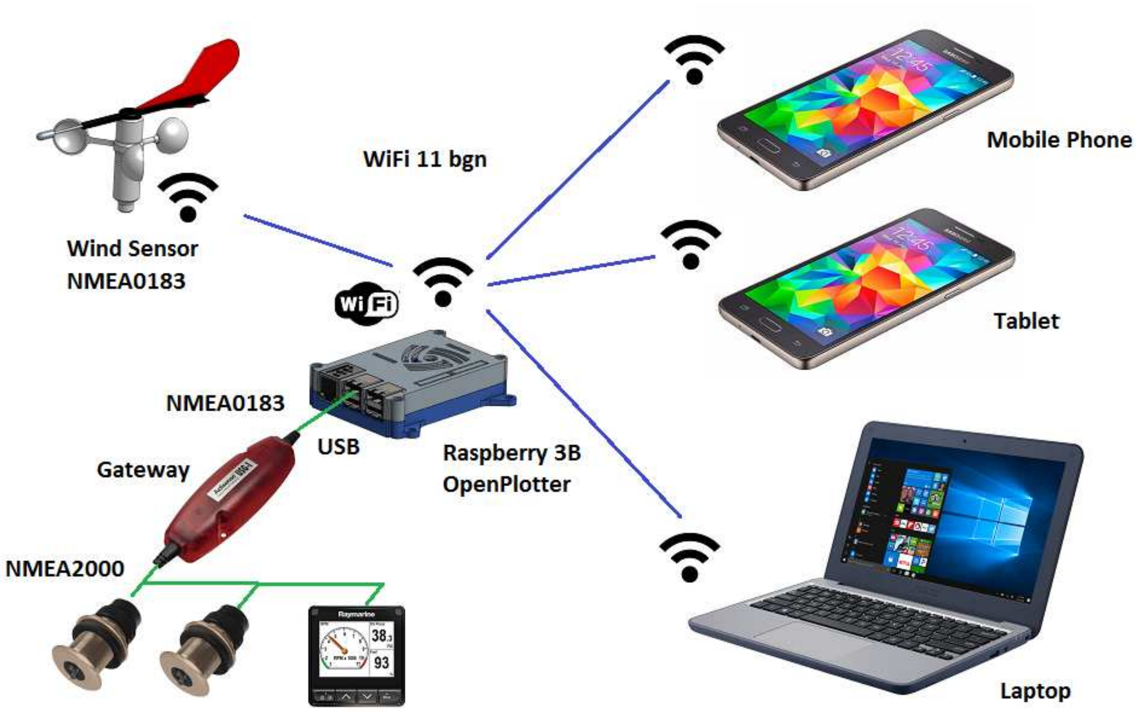

Fig.: Connection options with OpenPlotter as central data server and several end devices (Point to Multipoint)

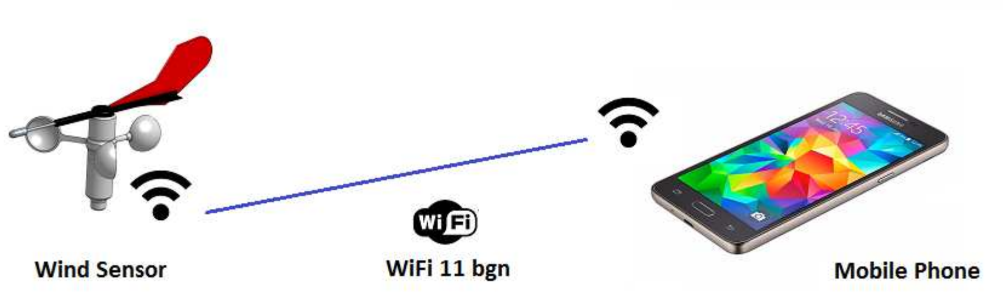

Fig.: Direct connection between wind sensor and terminal (point-to-point)

To parameterize the wind sensor, an access point is integrated in the wind sensor, which sets up its own independent network. The parameterization or a software update can be carried out via a web interface. The access point can only be used if there is no other connection to an application software.

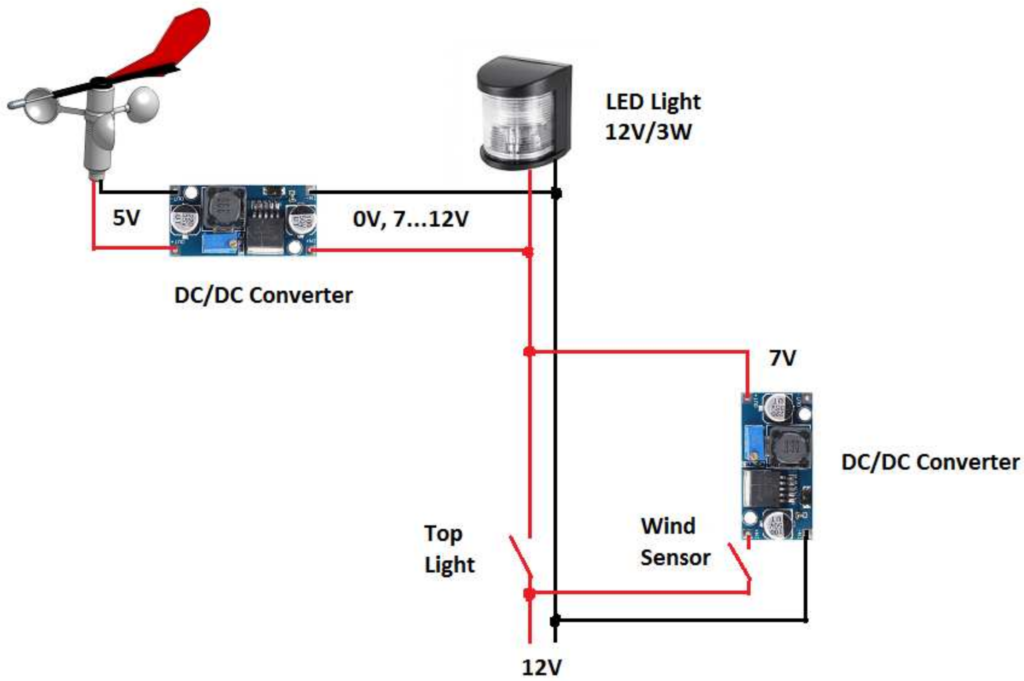

Fig.: Power supply via the top light in the mast

For the power supply of the wind sensor it is not necessary to pull a separate cable into the mast. You can take the power from the top light and supply the wind sensor with it. By means of an step down DC/DC converter, the sensor operates in the range between 7V...12V. If an LED lamp is used as top light, a reduced input voltage of 7V can be used to ensure that only the wind sensor is supplied, but the LED lamp does not yet light up. If you want both to work, you only have to apply a voltage of 12V. This means that 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°bei 0…40kn	
Type of function	magnetic, Hall sensor	
Ambient temperature	0…60℃	
Storage temperature	-10…80℃	
Air Humidity	0…100%	
Power supply	5V	reverse polarity protected
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	with 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 in such a way 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 falsified. 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.

Align the wind sensor to the ship's centre line (see marking) and tighten the grub screw.
Secure screws against accidental loosening with safety lacquer.

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 falsified.

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

If the ship is tilted, the wind direction display may be falsified.

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 may it be put back into 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 are 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 oiled with silicone oil. Brittle and cracked plastic parts must be replaced.

1.6 Disposal

At the end of its life time, 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

BY NC SA

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.

GPL Free Software Free as in Freedom

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 XXX.

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

						Angle
v	v	v	v	n	t	Resolution
[m/s]	[kn]	[bft]	[km/h]	[1/s]	[ms]	[°]
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 1314 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
Vaarkaart Friese Meren	WiFi, NMEA0183	Android	Full version, only one connection possible
DKW Kartensoftware	WiFi, NMEA0183	Android	Full wervion, 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
6) ESP8266: https://en.wikipedia.org/wiki/ESP8266
7) Wmos D1 mini: https://wiki.wemos.cc/products:d1:d1_mini
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: http://www.sailoog.com/openplotter
15) OpenCPN: https://opencpn.org/
16) AvNav: http://www.wellenvogel.net/software/avnav/index.php