

Figure 1. In practice, the sensor signals shown here may differ considerably from your own because the shape depends largely on the sensor construction. The shape change as a result of the wind will be hardly noticeable on a 'scope.

for the wind direction meter, leaving us just with the three-blade anemometer part.

**The principle**

The crux of the system is the little vane on one of the half spheres on the rotor. The vane causes a small acceleration or deceleration of the rotor, depending on its position relative to the wind direction. If we assume an angle reference point relative to the wind (on the fixed part) then it has to be possible to determine the wind direction using two sensors fitted at an angle of 90 degrees. The calculation method consists of first measuring the average value (of each sensor) over a couple of revolutions. Each change in the wind direction will result in a small variation of these two average values. Next, using an angular reference table with two inputs the microprocessor is able to figure out a 'wind vane' angle expressed in degrees. Hence in our wind speed and direction meter, only two Hall sensors are used supplying voltages proportional to their magnetic field. Each sensor supplies a sinewave-like voltage (Figure 1) whose frequency increases with wind speed while the average value is an indirect indicator for the wind direction.

One advantage of the specific design of the combined sensor is that the mechanical construction of the anemometer is far simpler than that of traditional meters while also reducing the risk of wear and tear as well as breakdowns. The instrument readout showing wind speed and direction is on an LCD as well as via a serial output that allows a PC or an (NMEA compatible) navigation instrument to be connected.

Even if mounted in a single enclosure, wind speed and wind direction meters typically employ two different sensors. Several solutions have become commonplace for the wind speed (anemometer) function, including optical sensors, generators and reed contacts. However, the classic design comprising a rotor with three half spheres causing a magnet to pass across a Hall sensor has the smallest number of disadvantages. The sensor type UGN3503 used in this project supplies a voltage of the order of 1 mV per gauss. These sensors, which are discussed in some detail, in the inset are impervious to dirt ingress and may be totally encapsulated. They consume little energy and unlike reed switches cause hardly any electrical noise.

Wind direction meters are usually realised using potentiometers and optical Gray encoders, but here, too, the linear Hall sensor is a good choice. The circuit presented in this article is a simplified version of the Rotavecta system whose main advantage lies in the total absence of mechanical parts

an ADC and then on to the processor. The 'limiter' block prevents overdriving of the capture/compare input on the PIC16F876. The processor is also busy driving the LCD as well as outputting an NMEA compatible serial signal for use by a PC or suitable navigation equipment. That wraps it up as far as the block diagram is concerned and we're ready to have a look at the

**Circuit diagram**

The schematic in Figure 3 can not be said to be overly complex, can it? At the heart of the circuit we find a PIC16F876 and a double opamp. There's a 218-page document on the PIC family waiting to be downloaded from the Microchip website mentioned at the end of this article. The PIC used here has Flash memory and is simple to program over a serial link. On board we find a 10-bit ADC of which two inputs are used, as well as a capture/compare module with one input used to measure the period of the reference signal. Using onamp IC1 (an LM358) the signal amplitude is adjusted for optimum use of the input span afforded by the ADC inside the PIC. The two UGN3503 sensor chips, IC5 and IC6, are linked to the main board by way of 4-way connector K3.

Together with two small loading capacitors, quartz crystal X1 provides Connector K1 allows the circuit to be hooked up to the PC's serial port. The LCD drive employs the RVW signal pair, besides Enable and RS, all on connector K2. Only four datalines are

**Block diagram**

No remarkable things are seen in the block diagram in Figure 2. The starting point is the pair of Hall sensors arranged at an angle of 90 degrees. Two amplifiers, one for each sensor, condition the sensor signals for use by

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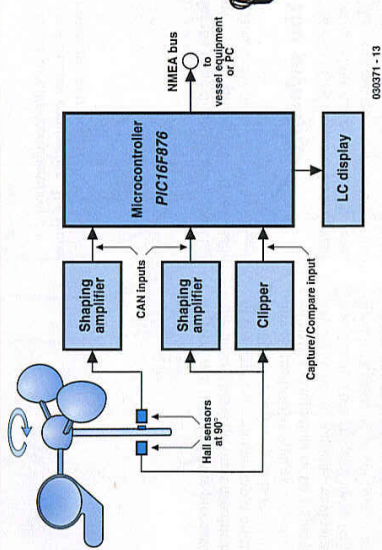


Figure 2. Block diagram of the combined wind speed & direction meter.

required in our case as the LCD is operated in 4-bit mode. Jumpers JP1 and JP2 serve to select between NMEA mode (JP1) and CALIBRATION mode (JP2). The on-board power supply gets its raw supply voltage from a 12-VDC mains adaptor. Alternatively, the instrument may be powered from a 9-V battery, in which case C7 and regulator chip IC3 are omitted and a wire link installed between the holes normally provided for the input and output pins of the 78L08.

## Sensor construction

The Hall sensors are accommodated on the small round board that's separated from the main board by cutting. The sensors are fitted at exactly the same height. Next, the board is fitted in the open end of the PVC tube and secured in place with epoxy glue. The spindle is made from a metal pin with a diameter of 3 mm, passing through a ball bearing or a Teflon sleeve bearing. In the prototype we used epoxy glue to secure the little magnet on to the spin-

## Building it

Figure 4 shows the component overlay. The copper track layout may be found on the PCB Layout pages towards the back of this issue. The board consists of a main section and a sensor section. The elongated shape of the board allows it to be mounted in a 32-mm

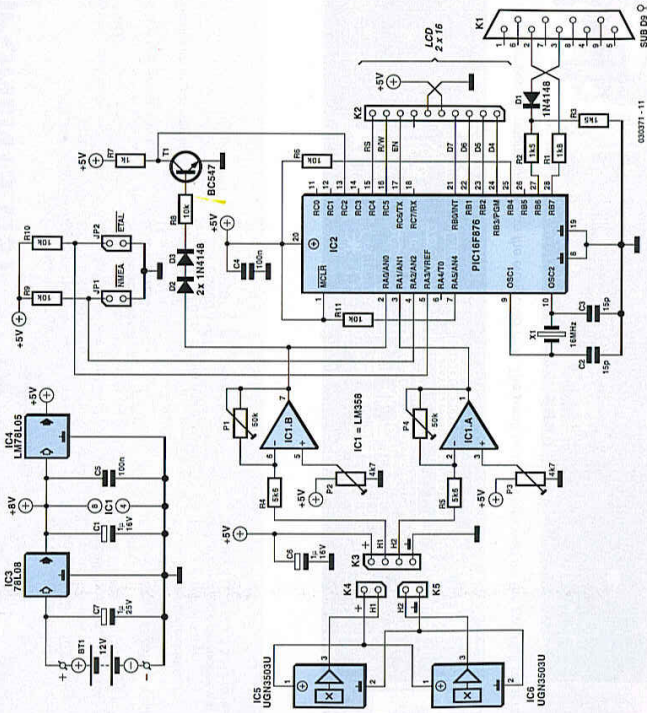
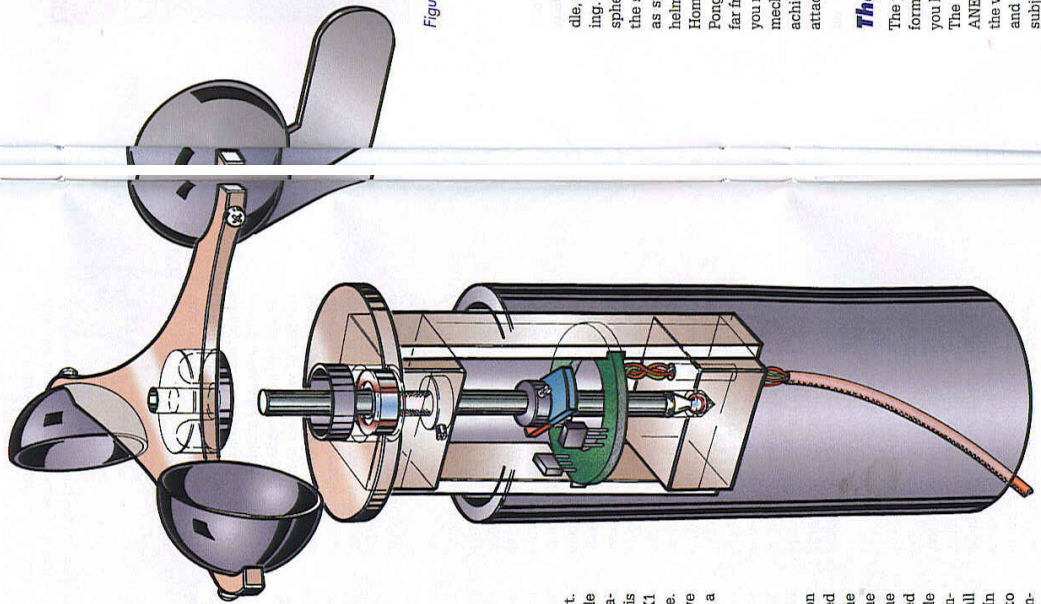


Figure 3. The circuit diagram remains happily uncluttered. Nearly all functionality is hidden inside the PIC micro.

die, as well as to secure the ball bearing. The rotor with its three half spheres has to be fixed securely on to the spindle (such rotors are available as spare parts from appointed Autohelm dealers).

Home construction of a rotor from Ping-Pong balls cut in half look attractive is far from easy. An unexpected difficulty you may run into is the need for perfect mechanical balancing, which is hard to achieve because of the little vane attached to one of the half spheres.

## The programs

The program VE16MPU.hex (in INHX8 format) may be blown into the PIC if you have a suitable programmer. The PC programs called TUNE and ANEMO, written in Delphi, serve for the wind speed/direction adjustments and the PC readout respectively. The subject will be reverted to under the

paragraphs on calibration.

The program file, ref. 030371-11, may be obtained from the Free Downloads section of our website, or on disk under the same order code. If you are unable to program a blank PIC, a ready-programmed one may be obtained through our Readers Services under number 030371-41.

## Amplifier adjustments

The first thing you need to do after switching on the supply voltage is adjust the four multitrans presets P1-P4. Your goal will be to make the IC1a and IC1b output signals cover the full range of 0.5 V to 4.5 V. This may be done with the aid of either an oscilloscope or the TUNE software. In the first case you closely watch the signals at pins 1 and 7 of IC1 while the rotor is

made to turn continuously by, for example, a hair dryer. Adjust P1/P4 (amplification) and P2/P3 (offset) to the best of your ability. Do make sure the sinewave signals remain between 0.5 V and 4.5 V and free from clipping. Aim to achieve the optimum setting shown in Figure 1. If you don't have an oscilloscope, use the software instead. TUNE offers a min/max function that draws a line along the discrete values measured. This requires the working meter to be connected to a PC. After starting the program, click on 'Min/Max' and view the message \*\*\*Min/Max\*\*\* after a few seconds.

## Wind speed calibration

The wind speed meter measures the period of one rotor revolution and then computes

# COMPONENTS LIST

## Resistors:

- R1 = 1k08
- R2, R3 = 1k05
- R4, R5 = 5k06
- R6, R8, R11 = 10kΩ
- R7, R9, R10 = 1k47kΩ

- P1, P4 = 1k47kΩ multiturn preset with top adjustment
- P2, P3 = 4k627 multiturn preset with top adjustment

## Capacitors:

- IC4 = LM78105
  - IC5, IC6 = UGN 3503 (Allegro)
- Miscellaneous:**
- X1 = 16MHz quartz crystal (Allegro)
  - X2 = 9-way sub-D socket (female), PCB case
  - X3 = 10-way pinheader
  - X4 = 4-way pinheader
  - X5 = 2-way pinheader with jumper
  - X6 = Standard LCD, 2 x 16 characters

- D1, D2 = 1N4148
- IC1 = LM 358
- IC2 = PIC16F876, programmed, order code **030371-41**
- IC3 = 78108

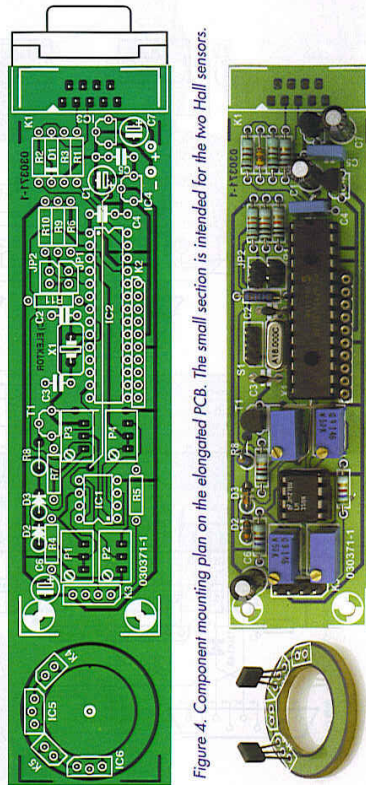


Figure 4. Component mounting plan on the elongated PCB. The small section is intended for the two Hall sensors.

speed =  $K_{anemo} / \text{period}$

The displayed speed is dependent on the constant K which takes a default value of 35500. The adjustment program TUNE calculates the constant based on a comparison between measured speed and real speed (obtained, for example, with the aid of a car speedometer). Adjusting the speed factor Kanemo (if necessary, adapt the initialisation value in the .hex file) boils down to comparing (a) the speed shown on the LCD display with (b) the real speed and (c) the speed already stored in memory. In each case it is necessary for the PIC to be read out first. The program TUNE will then show 'x.y (z)' where  
 $z = \text{speed factor} = y + 255x$

## Sensor calibration

Due to the small differences in force and direction of the magnets we're forced to create individual calibration

curves for each UGN3503 sensor chip. The process places rather high demands on the test 'wind quality'. The air stream produced by a hair dryer is too concentrated for an accurate direction measurement — nothing beats a real air stream.

Here we avail ourselves of the adjustment software. To enable the system to calculate the wind direction, each sensor is linked to a lookup table with 72 values (for 5-degree steps). The adjustment program employs 8 points for the interpolation of each curve, so a total of 16 values is needed. In other words, two values have to be measured with each angle of 45 degrees. This calibration method may take a while. In between two measurements, the wind meter has to be turned 45 degrees while making sure the readout remains stable. The values may be viewed continuously on the LCD or on the PC display (via the COM port) after the command 'read PIC'. They have to

be entered in a table like the one shown in Figure 5. Once the table is complete, the function 'Curve' computes the 72 values we need, on the basis of the 16 actually measured values. Next, the curves are actually plotted using 2 times 72 reference points.

## Practical use

After an initial phase in which the system has to determine a number of average values, the wind speed & direction meter will transmit its data to the LCD as well as the NMEA output. Although the NMEA 0183 (or NMEA183) standard is a bit old, it sees wide use in marine electronics. In our case, the NMEA sentence reads:

\$WIVWR,dit,L,vit,K

where \$WIVWR should be taken to mean 'Weather Instrument', 'VWR' is the standard prefix for anemometer information, 'dit' is the wind direction

# The UGN3503

## Characteristics

The type UGN3503 Hall sensors (models IT, U and UA) are capable of detecting magnetic flux changes of a magnitude so small they can not be measured with a reed switch. Every sensor contains a Hall effect detector, a linear amplifier and an open-emitter output stage. A magnetic field perpendicular to the chip produces a current change, the resultant potential difference causing the Hall effect voltage. This voltage is proportional with, among others, the magnetic field strength.

## Operation

In the inactive state, (I<sub>b</sub> = 0 G), the output voltage level is normally half the supply voltage. A magnetic South pole opposite the active part of the sensor produces a voltage above this level, and a North pole, a voltage under this level. Model -U is not recommended for new design.

PVC tube, dia. 32mm, length approx. 200mm

PCB, available through **The PCBshop** Disk, project software, order code **030371-11** or Free Download

PCB copper track layout on 'PCB layout' page elsewhere in this issue. PCB artwork file also available as a Free Download.

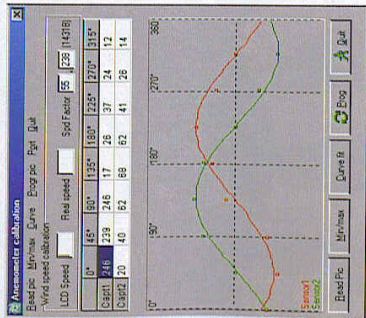


Figure 5. Once TUNE has been launched you can start collecting calibration data.

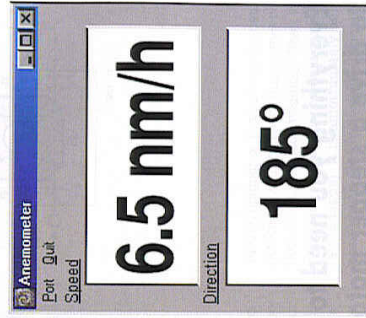


Figure 6. An example of the ANEMO software in action. The values are simultaneously shown on the LCD.

in degrees and 'vit' is the wind speed in km/h. The program ANEMO allows everything to be viewed on your PC in real time.

Admittedly the construction of our wind speed & direction meter requires due attention to mechanical details, but once calibrated the instrument will reward and surprise you with its totally efficient operation.

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# Web pointers

- PIC16F876 family datasheets: [www.microchip.com/download/lit/pline/picmicro/families/16f87x/30292c.pdf](http://www.microchip.com/download/lit/pline/picmicro/families/16f87x/30292c.pdf)
- Beaufort scale: [www.zeinet.co.uk/signs/weather/Met\\_Codes/beaufort.htm](http://www.zeinet.co.uk/signs/weather/Met_Codes/beaufort.htm)

0	Calm	<1 knot
1	Light air	1-3 knots
2	Light breeze	4-6 knots
3	Gentle breeze	7-10 knots
4	Moderate breeze	11-16 knots
5	Fresh breeze	17-21 knots
6	Strong breeze	22-27 knots
7	Near gale	28-33 knots
8	Gale	34-40 knots
9	Severe gale	41-47 knots
10	Storm	48-55 knots
11	Violent storm	56-63 knots
12	Hurricane	>63 knots