Simple DIY Angle of Attack (AoA) Indicator

Why you want an AoA Sensor

Stall / Spin accidents are the biggest single cause for fatalities in gliding (see Pirker, Herbert: How we could reduce fatal gliding accidents by about the half). What if we could avoid at least some of these fatalities with a stall warning device?
In flying we are used to fly at certain speeds, when we really want to fly at a certain angle of attack. What is the approach speed of your glider? How much does it change, if your gliders weight changes? What´s your minimum sink speed? What´s your minimum sink speed at 15, 30 or 45 degrees bank angle? What airspeed should you fly during a winch launch?
The AoA Indicator can help you with all these questions. It´s not about giving a scientific measurement, but to aid to make your flying safer and more efficient. One way to indicate AoA is the “Seitenfaden”, basically a yaw string attached on both sides of the canopy, proposed by Akaflieg Köln. The text is in German, but you can probably get the gist of it from the sketches. The Seitenfaden is a very simple solution, but suffers from sensitivity to sideslip. Another rather simple and inexpensive solution is proposed here.

Ways to measure AoA

There are many types of AoA sensors available already. The most common sensors use either a vane or differential pressure sensors. Some examples are
Five hole probe explained at NASA website
DIY vane and hall effect sensor at www.charlesriverrc.org
DIY vane and rotary encoder at http://paparazzi.enac.fr
Commercial vane type sensor at http://www.engineerlive.com
Reed horn (stall warning device) at http://members.eaa.org

Build an AoA Sensor

This is work in progress, and no warranty of any kind is implied. This design is provided for your private (or clubs) use.

Basic Principle

The sensor is of a vane and rotary encoder type. A microcontroller board reads data from a rotary encoder and transfers it as a NMEA type serial stream over a Bluetooth connection. The serial stream can be used to display angle of attack on a dedicated AoA indicator gauge, or on a PDA already available in most gliders.

The Chip

The AoA sensor is built around rotary encoder chip made by www.ams.com. You can see the whole product family at Magnetic-Position-Sensors/Magnetic-Rotary-Position-Sensors. It evaluates the magnetic field of a small rare earth magnet over or under the chip and determines its angular position. There is no mechanical contact between the magnet and the chip, and hence no mechanical friction (other than from the ball bearing we are going to use).

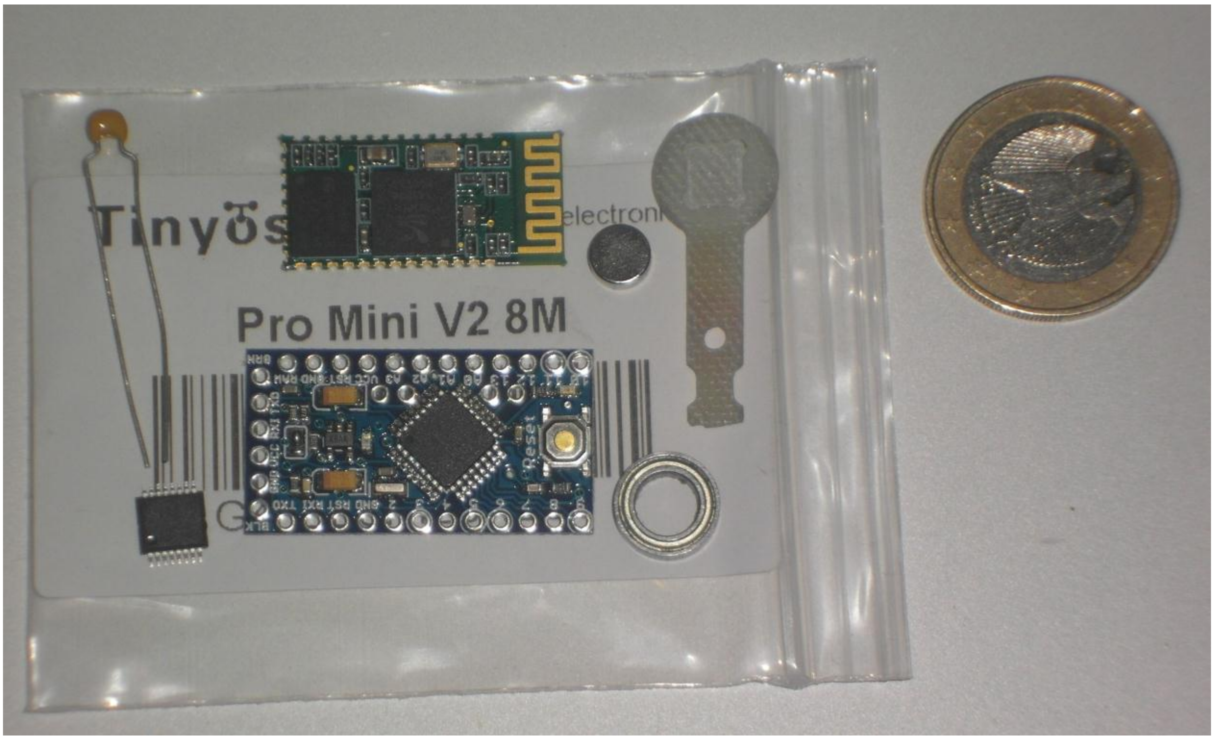
The Indicator

There is no dedicated indicator available yet. The sensor mimics the NMEA sentence of a LX variometer, and transfers data as a pretended lift or sink. This allows us to watch the sensor output on the vario gauge implemented in popular open source XCSoar gliding software.

We have opened Ticket #2370 as an enhancement request for the implementation of a dedicated AoA gauge in XCSoar. If you want to develop the XCSoar AoA gauge please let us know, and we will provide a sensor module.

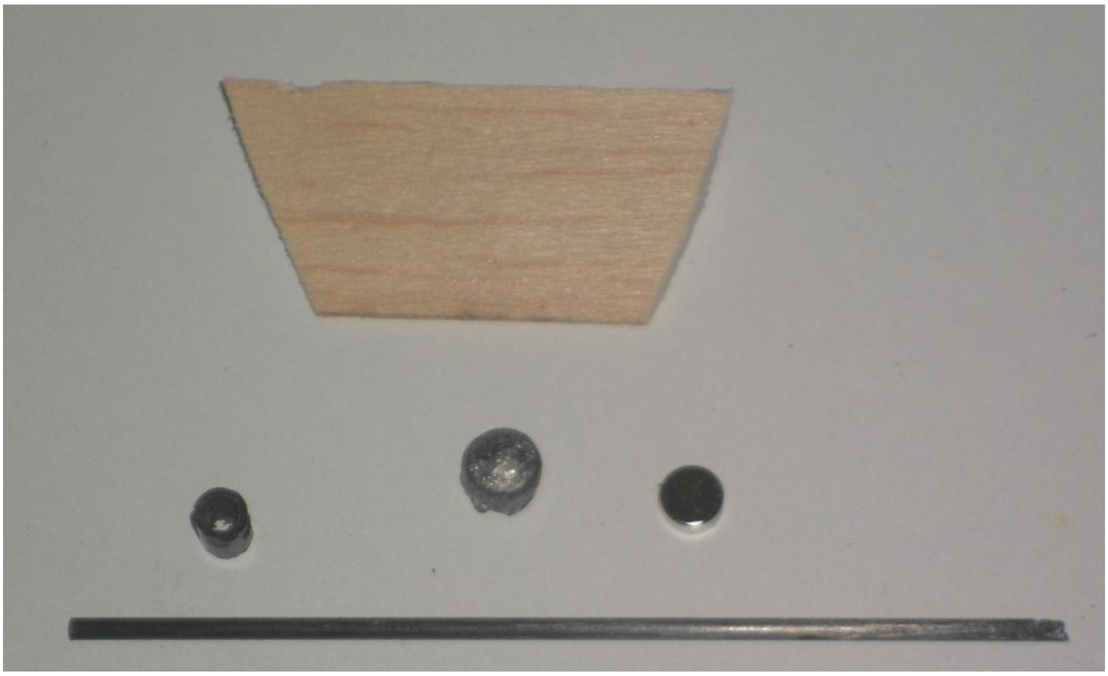
The Quick and Dirty Way

The quick and dirty way to build the sensor uses an AS5045 sensor with 12 bit resolution, an Arduino Mini Pro microcontroller board and a standard Chinese Bluetooth module. AMS is generous enough to offer samples of the chip and magnet (see link to sensor family above), Arduino and Bluetooth modules are available from many sources, and no custom PCB is required. This means you can build this sensor for small money, and without much sourcing of parts.

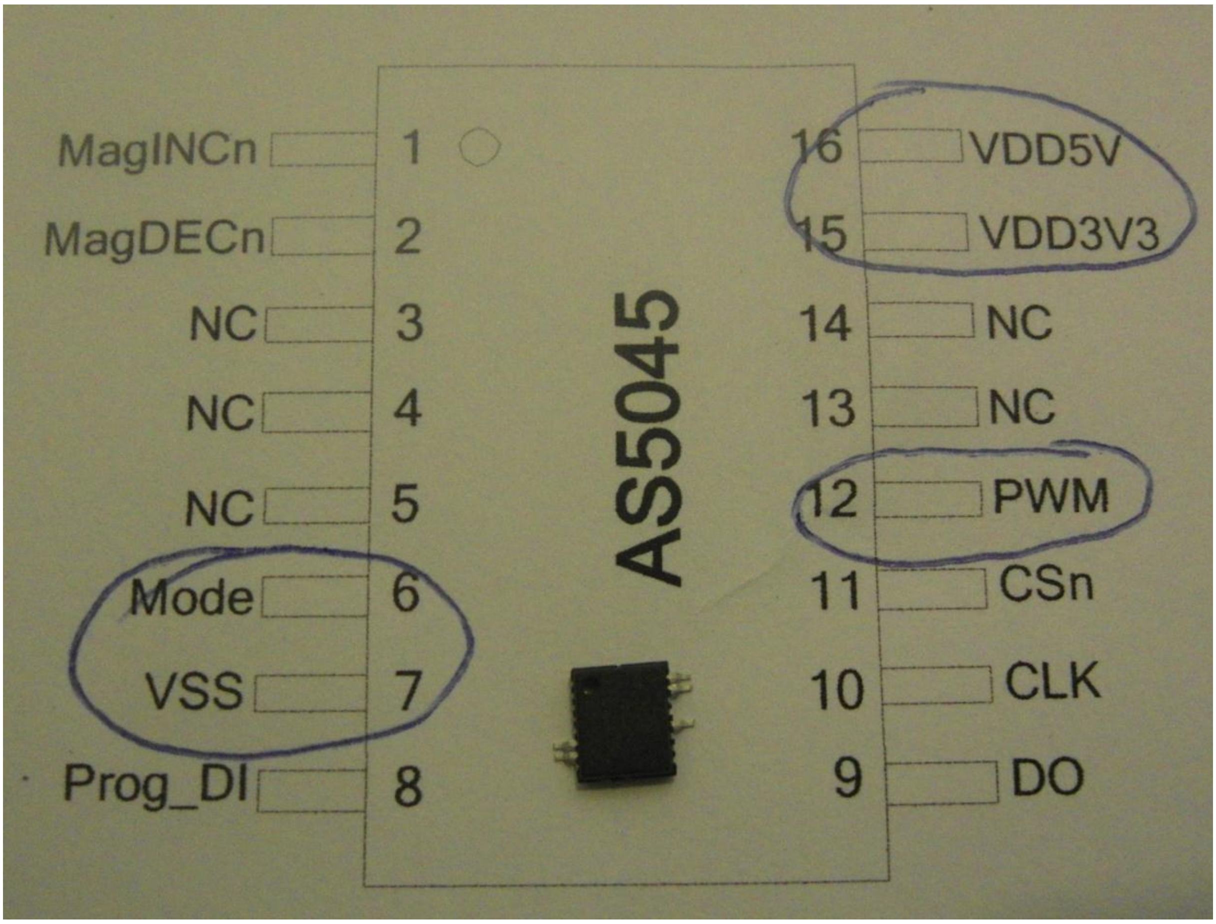


You need

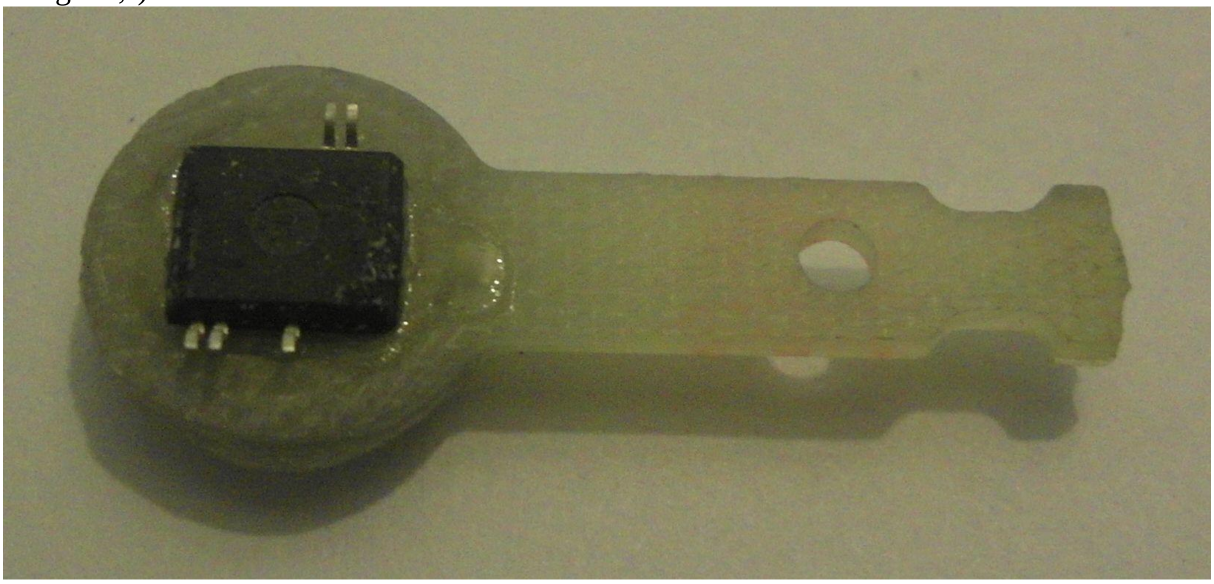
- Arduino Mini Pro 3.3V / 8MHz
- Bluetooth module (this one is a Chinese HC-05 from Ebay)
- AS5045 chip and rare earth magnet
- Ball bearing for the magnet
- Some kind of carrier plate for everything (part between BT module and coin). I made it on a CNC router with recesses for bearing and chip, but some part cut with a jigsaw will do fine also)
- 100nF capacitor
- 2mm carbon or steel rod, approx. 100mm long
- 5mm carbon tube, 5mm long (or some other way to mount the rod to the magnet)
- Material for the wind vane, I used a small length of a model aircraft trailing edge
- Weight to counter-balance the vane
- Some small stuff like wires, connectors, tin, adhesive tape, heat shrink, maybe a LiIo cell and other stuff depending on your preferences



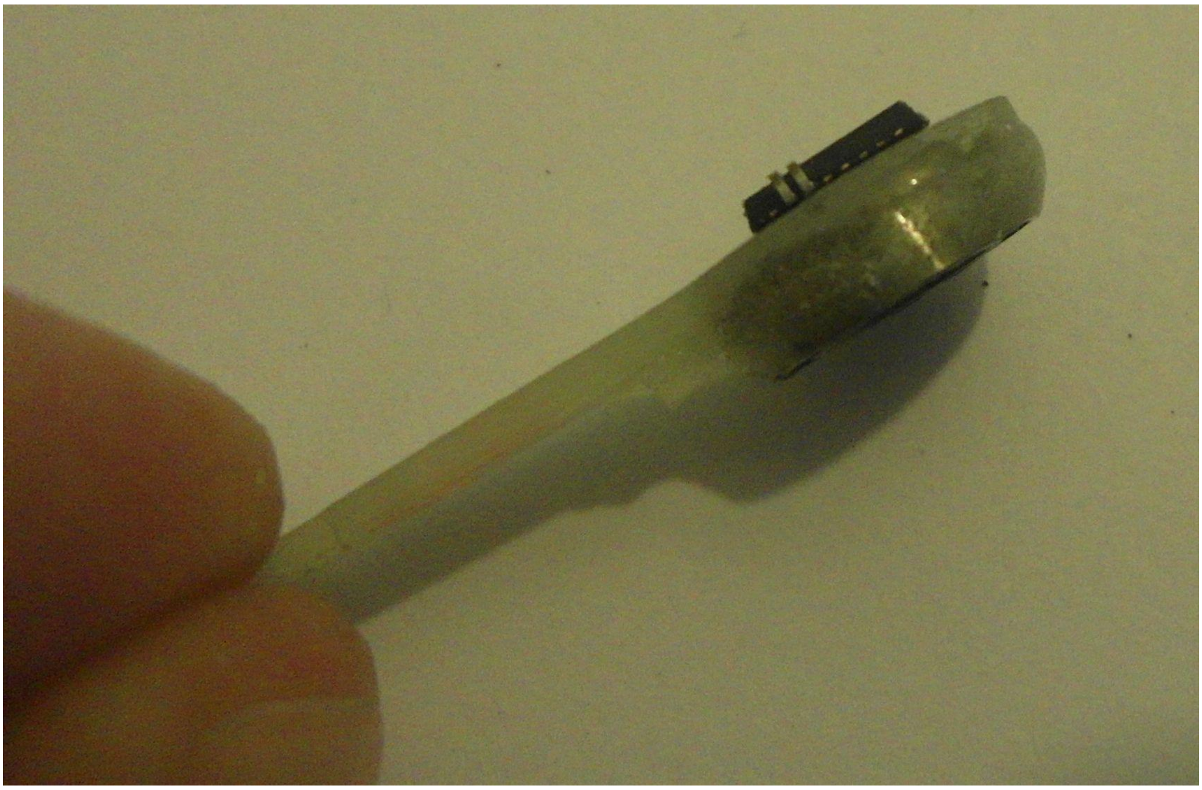
We start by bonding the ball bearing to the carrier with fast curing epoxy. Bond between the bearing outer diameter and the carrier and make sure that the bearing does not get clogged by resin. A wooden tooth pick worked well for me for application of the resin.

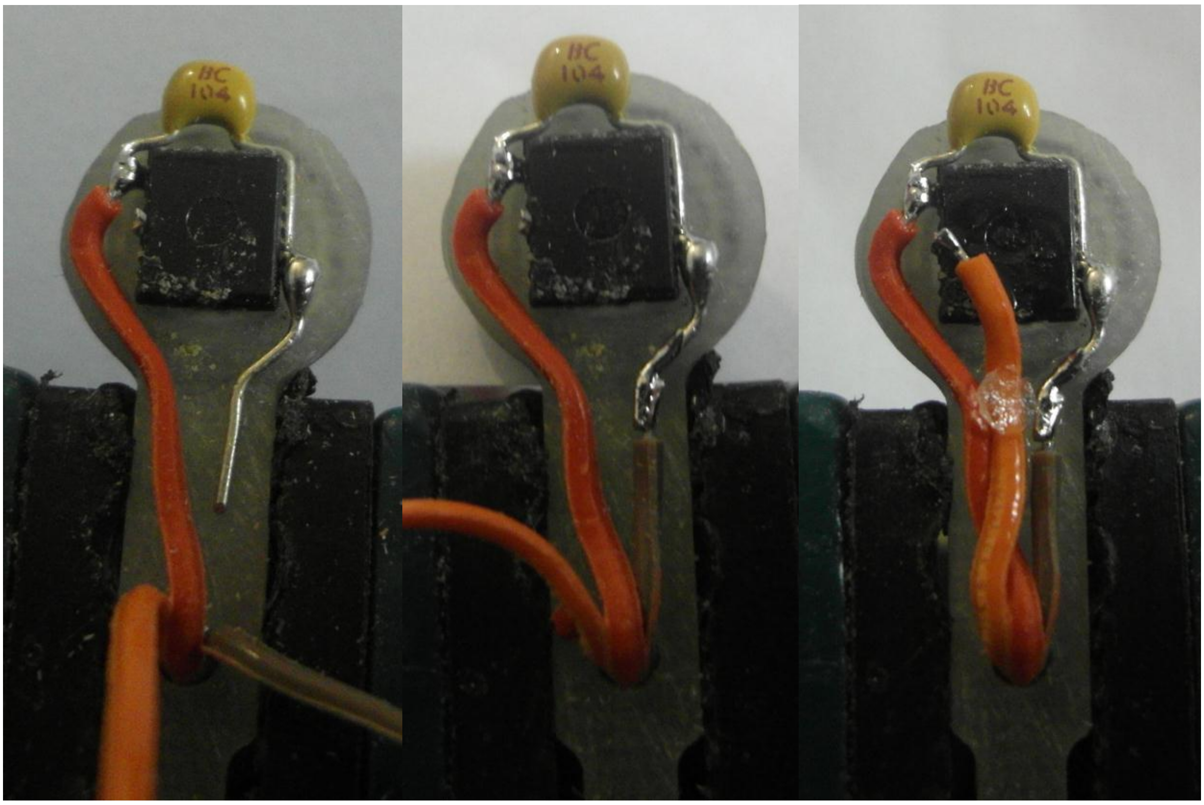


The chip has 16 pins and is really tiny. Fortunately, we only need five of its pins, so I removed the rest of them by bending and breaking them off with a pair of tweezers. Considering my soldering skills this looks much better now. Your local chip designer may disagree ;-)

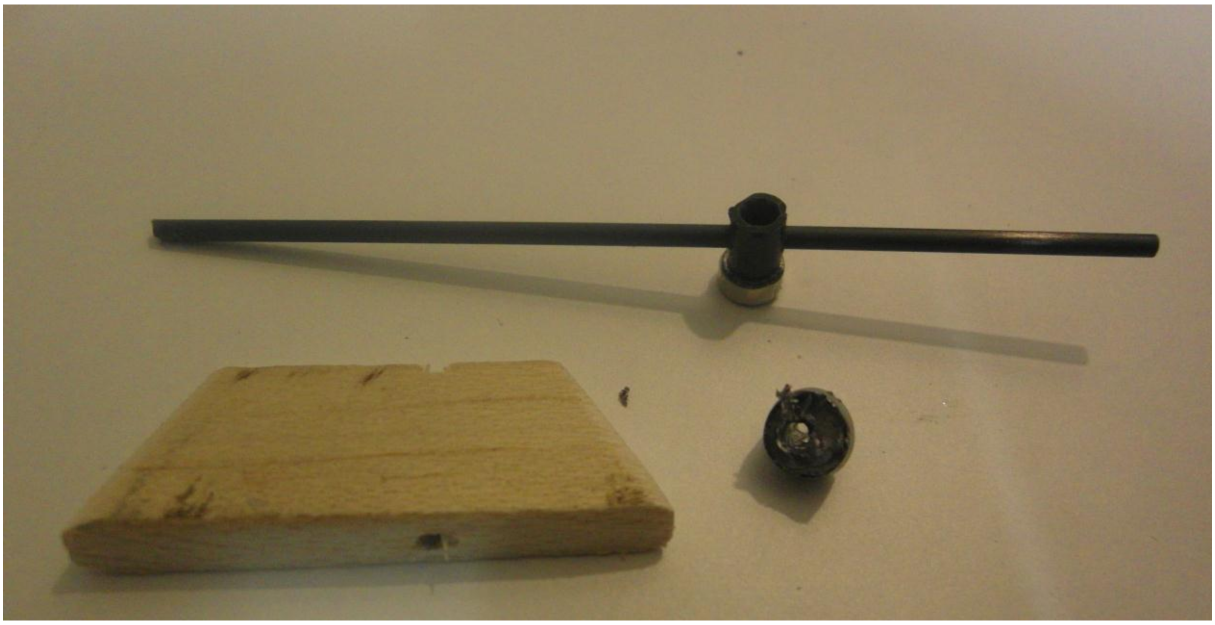


With most of its pins removed, the chip is bonded to the carrier in a dead bug style, lying on its back and legs up.

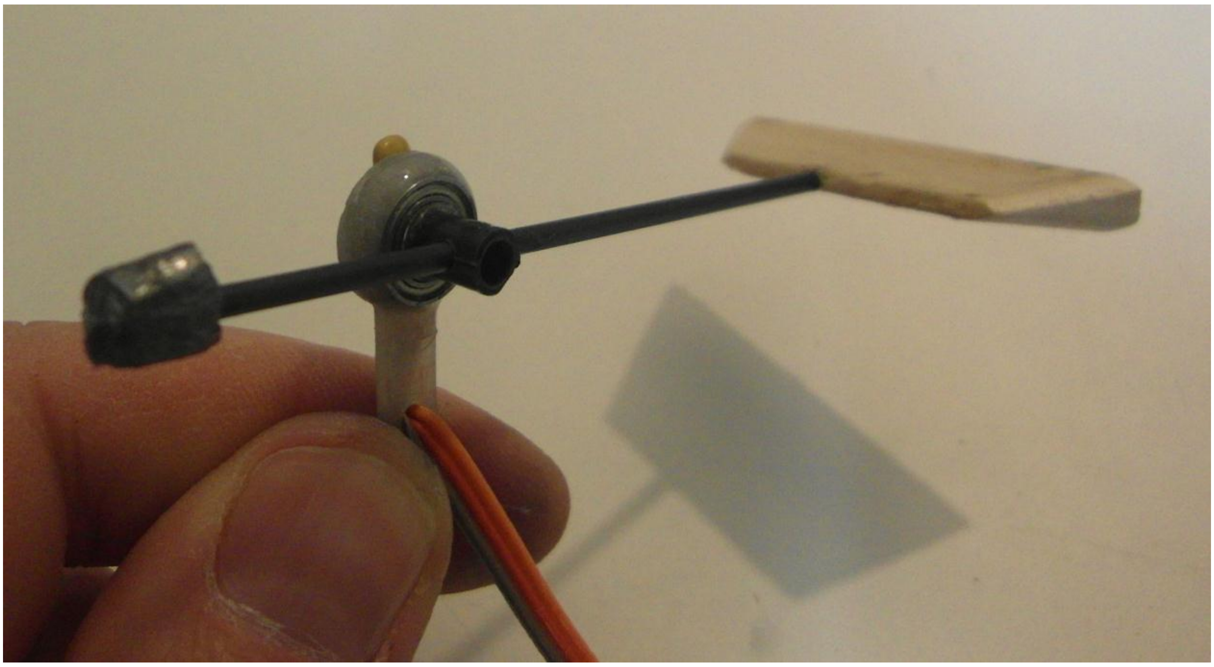




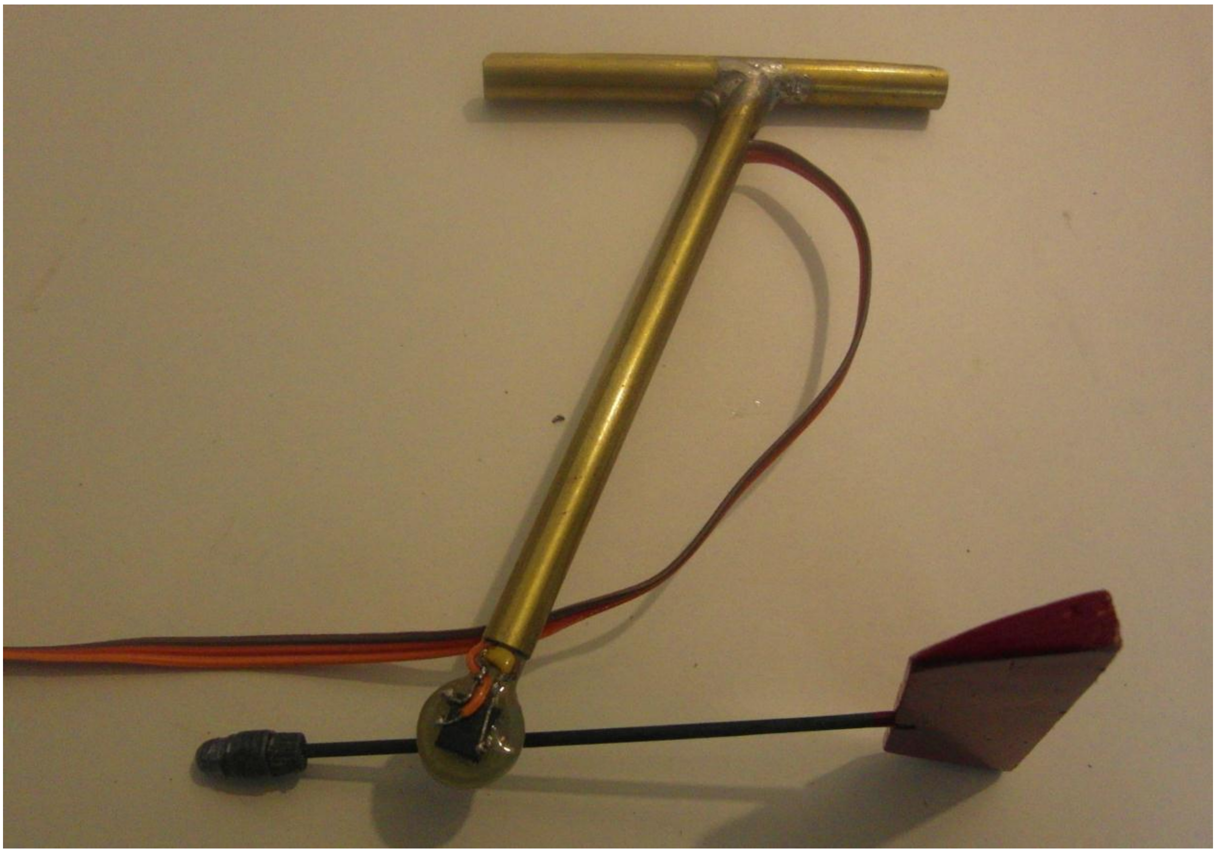
Solder the capacitor and wires to the pins of the chip. When done, secure everything with a drop of medium cure cyano glue and cover it with a few drops of fast curing epoxi.



Bond the short carbon tube to the magnet with epoxy. Be careful not to get any resin on the outer diameter of the magnet. The 2mm bore for the carbon is best made before you cut the short length of 5mm tube. The wind vane and the counterweight are drilled and bonded to the carbon rod with cyano. Note that the vane is not drilled in its symmetry axis, but slightly offset, to give a vane that is symmetric about the carrier plate.



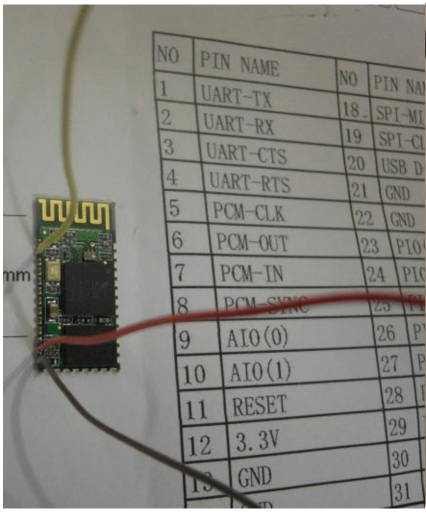
Let the magnet snap in the bearing, and you are done with the sensor!

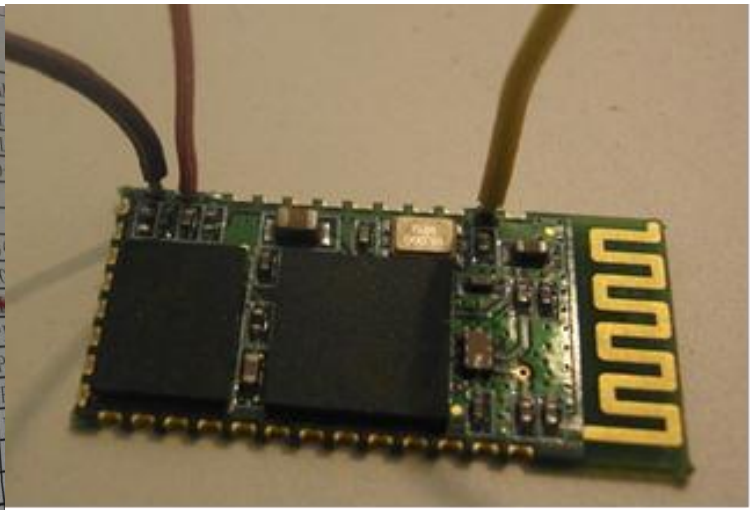


All assembled with two brass tubes, ready for mounting on the TE probe.

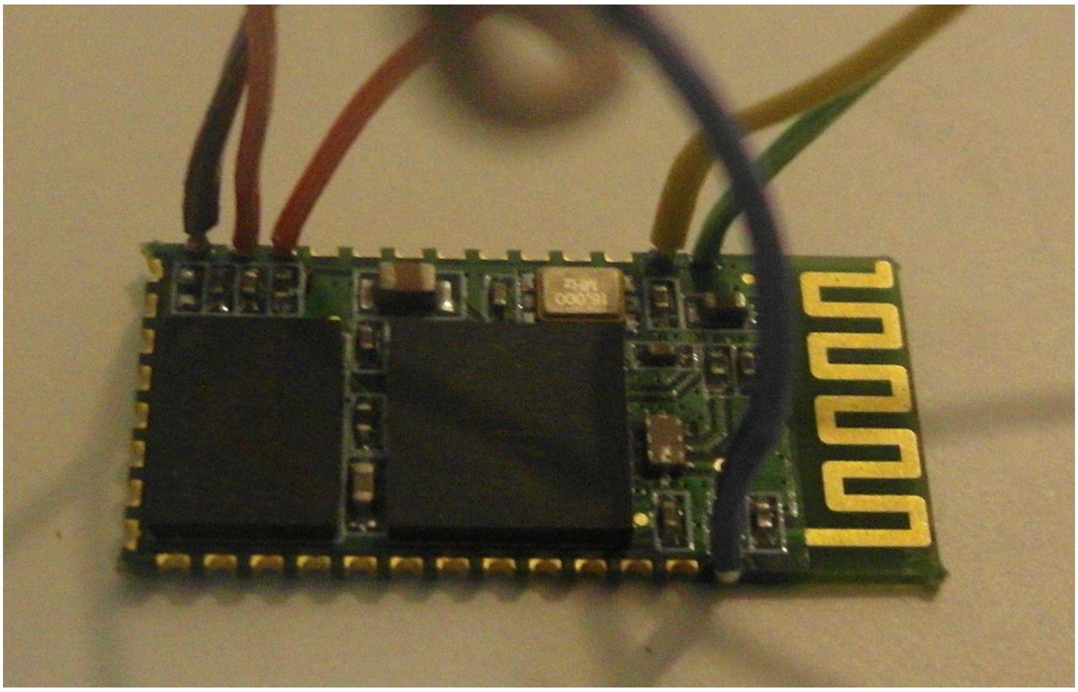
Sensor mounted to the TE probe.

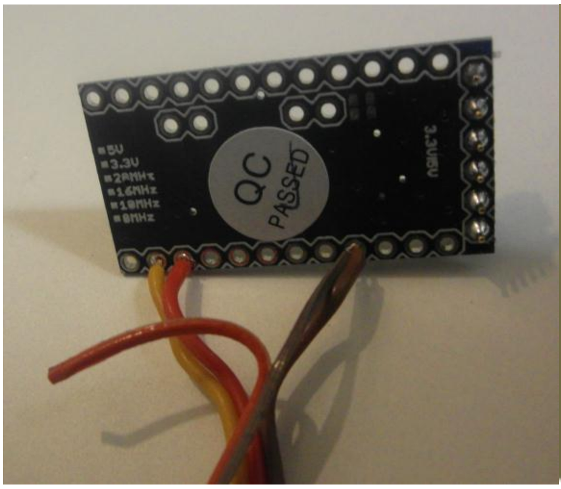
Let´s continue with microcontroller and Bluetooth.



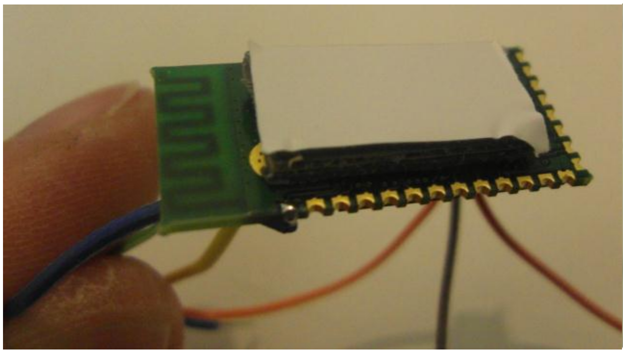
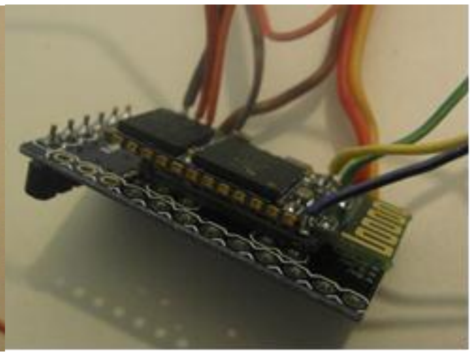


For basic operation, we only need three wires going to the BT module. UART RX on pin2 (yellow), 3.3V on pin 12 (red) and GND on pin 13 (brown).
I decided to also add UART-TX on pin 1 (green), Reset on pin 11 (orange) and AT command mode select on pin 34 (blue) to have some more options for controlling the BT module from the Arduino. This also allows programming of the Arduino over Bluetooth (Thank you Hari & Kimmo!).
Before you proceed, make sure that the BT module is configured and working properly. My settings are module operates as slave, 57600bd, 1 stop bit, no parity, name and password for pairing according to your taste.
It may also make sense to program the Arduino over the socket header before you go on and connect the BT module, so you have lower chances to do something wrong. You can download the software for the Arduino here. It reads the pulse length output from the AS5045 chip, calculates AoA from it and sends it as NMEA data over the serial port to the BT module. The program it is made from code snippets found in the net, adapted and glued together without real programming knowledge. If you can do it better, please let me know.

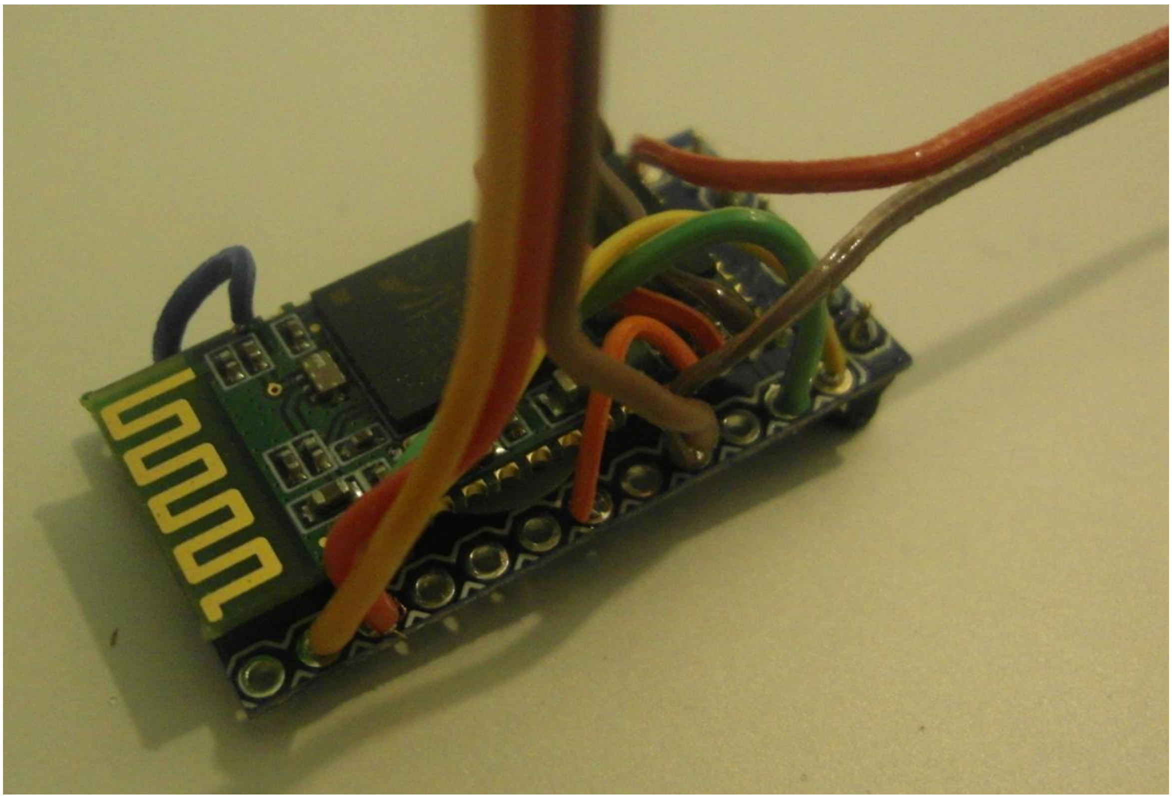




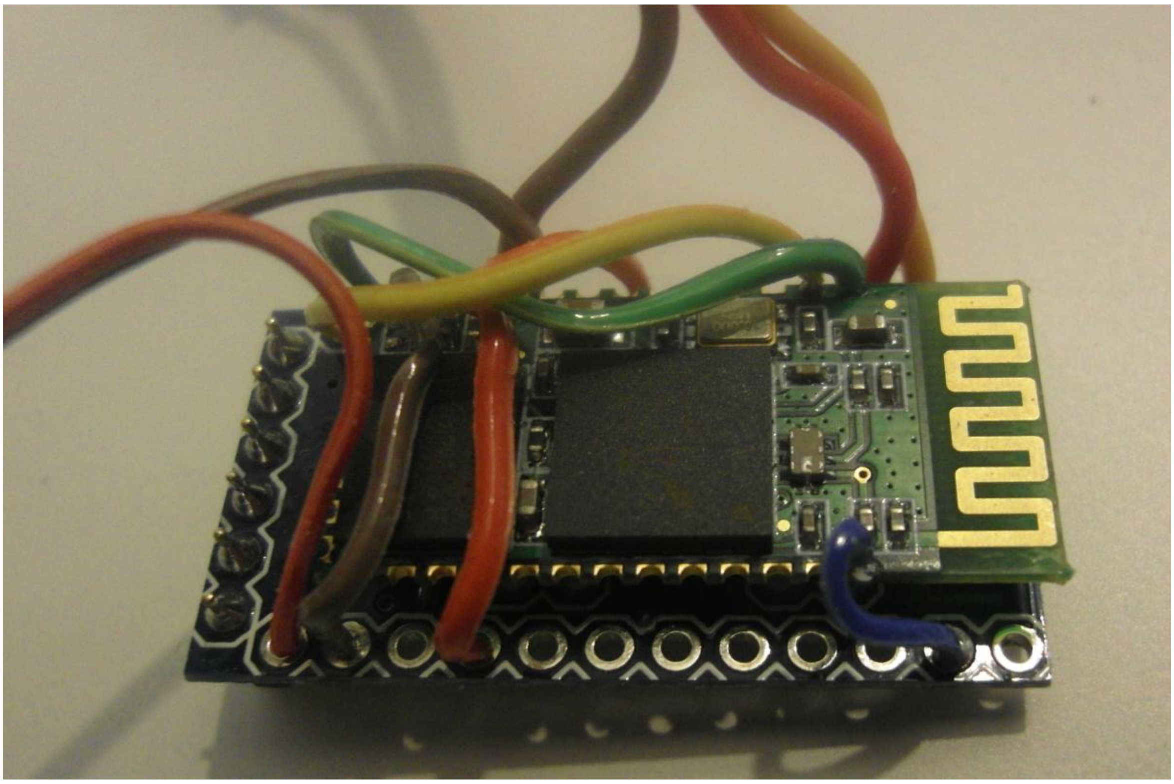
A socket header is soldered to the narrow sider of the Arduino for programming. Sensor Vcc (red) connects to pin 7, sensor PWM signal (orange) to pin 8. Sensor and power supply GND (brown and black) are soldered to one of the Arduinos ground pins.

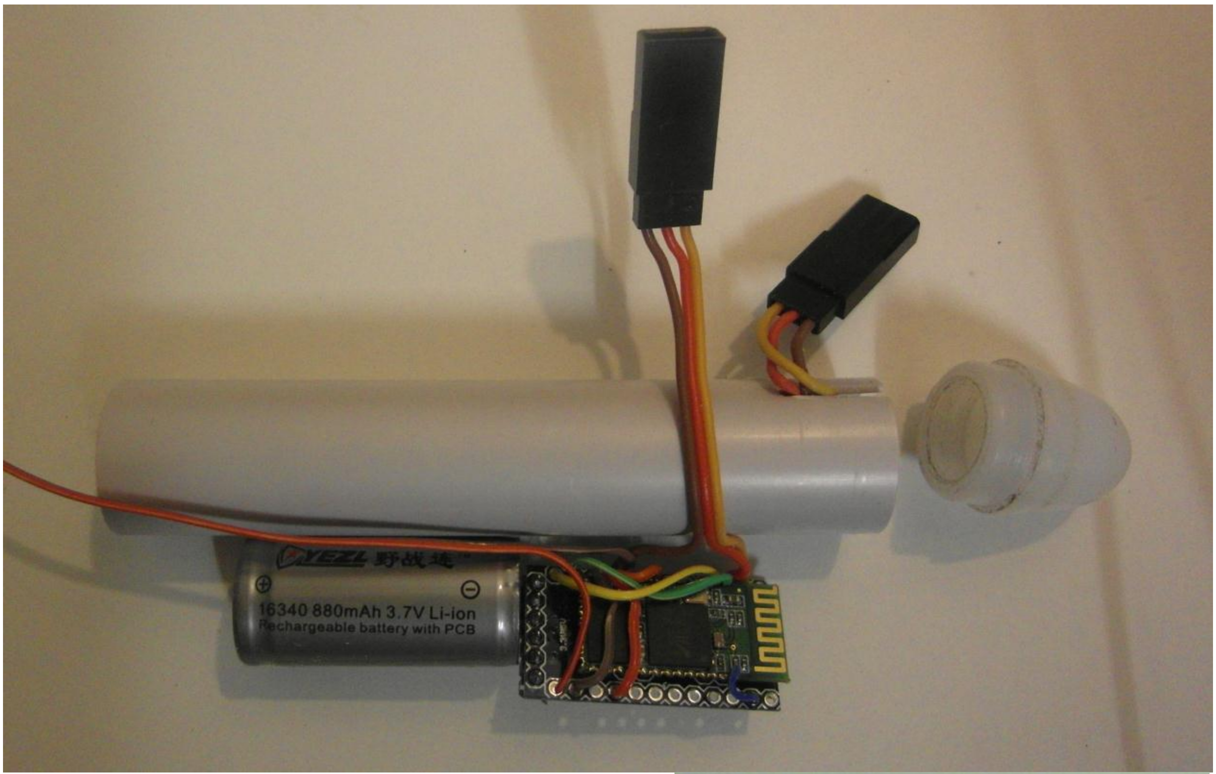
Bond the BT module to the Arduino board with double sided sticky tape. Use thick tape or a spacer to make sure that there is some gap between the boards.

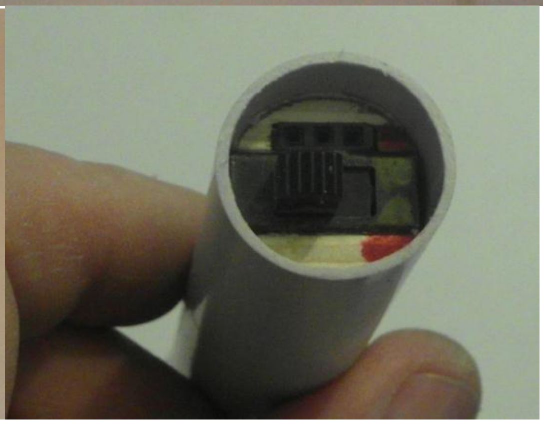


BT module TX (green) wire goes to RXI, BT module RX (yellow) to TXO, BT module RESET (orange) goes to pin 3. AT command mode select (blue) goes to pin 11, BT module VCC (red) to Arduino Vcc, BT module GND (brown) to Arduino GND. Connect positive power supply wire (red) to Arduino RAW input, and you are done. You can now wrap everything in some heat shrink sleeve and put it in your tail fin battery compartment, or in some free space between fin and elevator.



If you want to use your AoA sensor on different gliders, you may want to build a nice self-contained module with battery, on-off switch and charging socket. This is the most portable solution, allowing use even with club gliders.





I suggest using a LiIo battery with an integrated protection PCB to avoid overcharging and deep discharging of the battery. The battery shown lasts for more than 12h of continuous operation, which should be enough for most pilots.

The Professional PCB

Alternatively we also developed a PCB as compact as possible. It contains sensor, microcontroller and Bluetooth module on one PCB, but the sensor part could be separated by a cut if required. The sensor part of the PCB contains the magnetic rotary encoder IC and the ball-bearing holding the magnet, actually mounted under the IC package in the PCB for good robustness and position accuracy. The second part connects the ultra low power Microchip Controller PIC16F1825 to the Bluetooth module and the sensor. It holds also the voltage regulator and reverse polarity protection to be save to connect the AoA also on the glider on-board voltage of typically 12V.

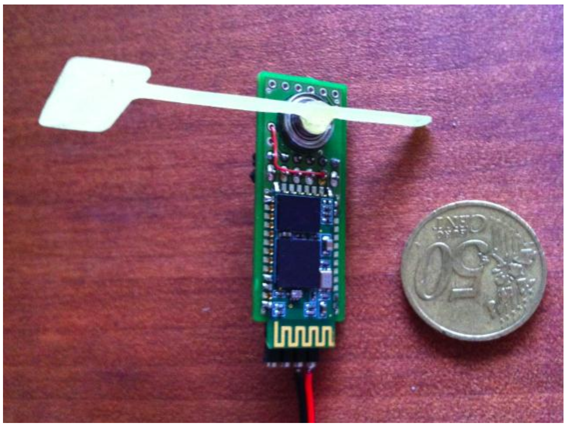


Figure 1 Frontside with Sensor and PIC uC

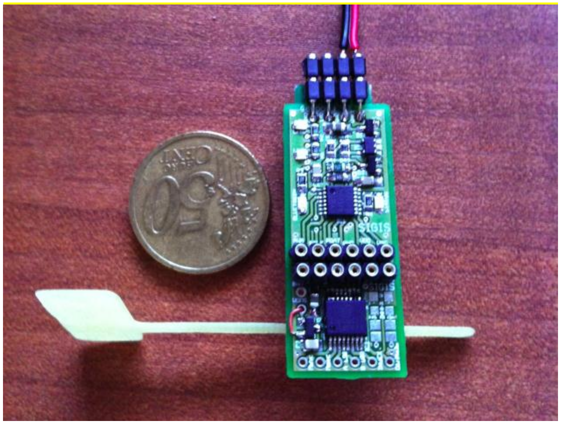


Figure 2 Backside holding the Bluetoothmodule and the ballbearing including magnet

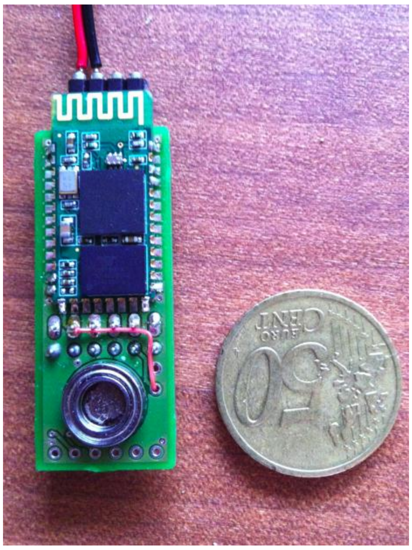


Figure 3 ball-bearing with magnet

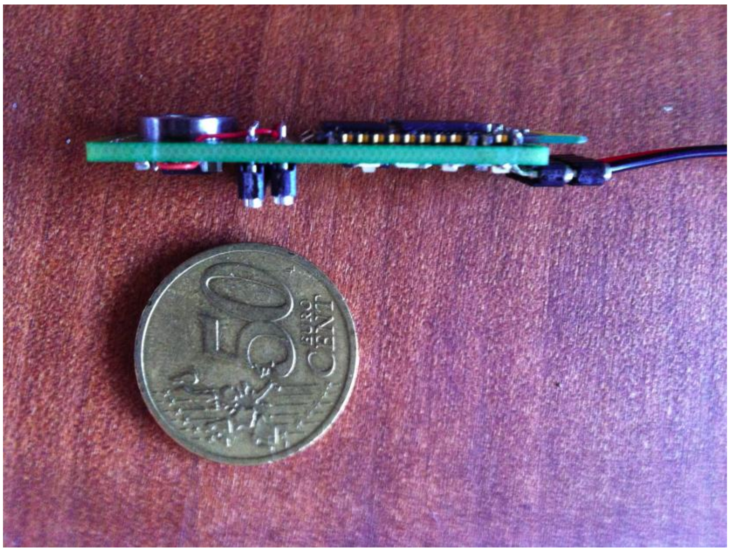


Figure 4 Sideview showing the PCB embedded ball-bearing and the Bluetooth module sandwitch

For optimal power consumption control the sensor can also be switched on and off, even remote by the Bluetooth master. The micro controller software allows also the auto-zero in flight.
The PCB can be connected to any power supply in the glider. Anyway the plan is to keep complete independency for optimal aerodynamic placement either at the TE-probe or on a pole mounted to the glider wing-nose (Test-Flights tbd.).

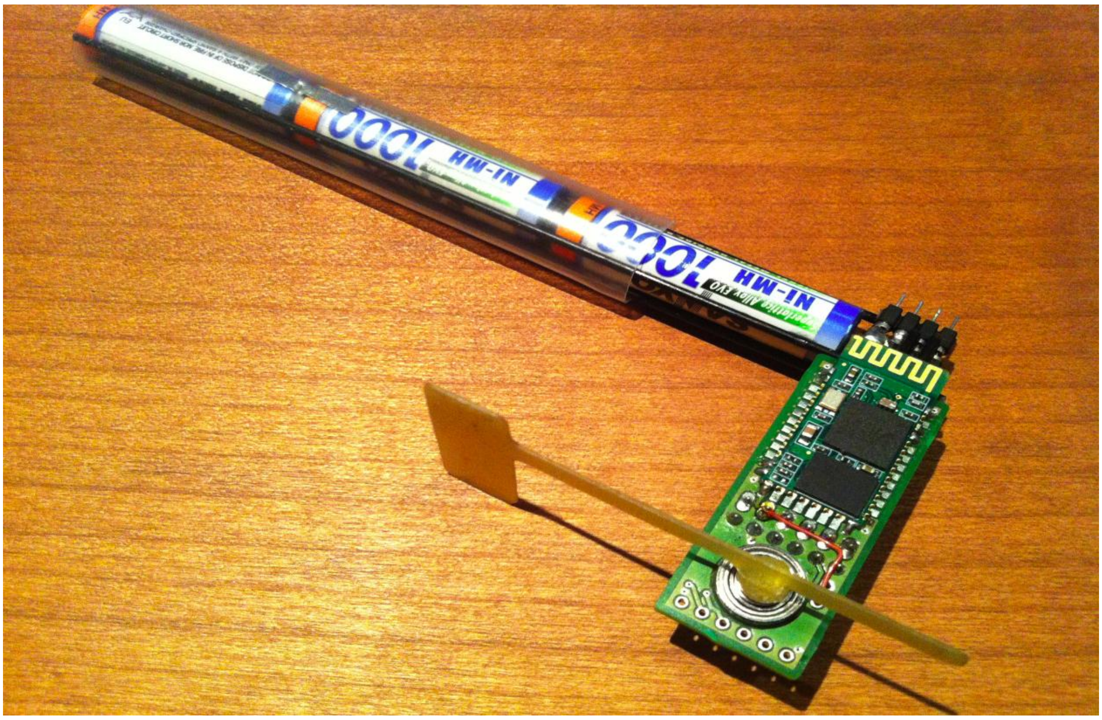
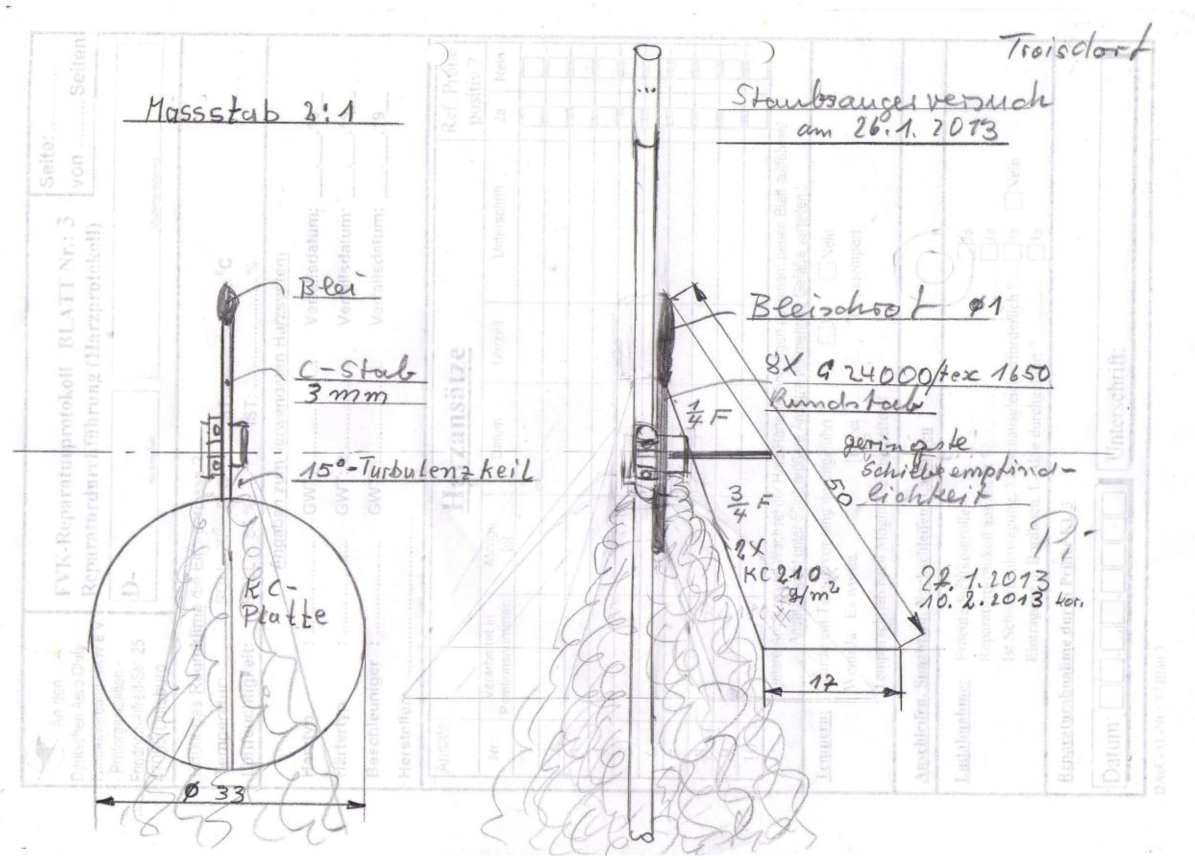


Figure 5 Independent power supply used also for simple mounting to the TE probe or other aerodynamic optimal placement (e.g. in Front of the wing-nose)

More details to be followed.

Wind Vane

Note that the two wind vanes shown are interchangeable, each vane can be used on each version of the sensor. Two additional forms for the wind vane are proposed by Siegfried Piontkowski, see below.



Contact

If you have ideas for improvement or want to help with testing or implementation in XCSoar, please send a mail to AoASensor@akaflieg.at