Analogue Wind Vane with Self Calibration

by **Tecwyn Twmffat** on May 3, 2016

Table of Contents

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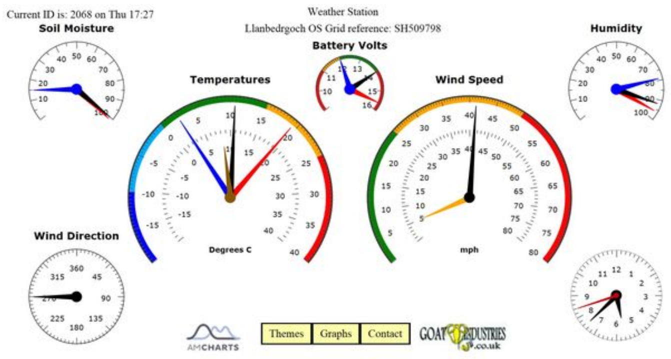
I live on an island in the Irish sea called Ynys Mon which was once inhabited by the Romans, the Vikings and is still inhabited by Druids. Me, I'm just a bloke who likes inventing things and doing the whole 'Alternative' thing. Most rewarding experience: Playing music to large audiences at festivals. Most dangerous experience: Mixing psychoactive drugs with Buddhist meditation. Most difficult experience: Trying to work out what the hell I'm here for! Plans for the future: Would like to build a 'Passiv Haus'. Best advice: Get off the well trodden paths.

Intro: Analogue Wind Vane with Self Calibration

As the amazing online GPRS Weather Station project continues, we have yet another upgrade to the vast array of sensors with a professional analogue wind vane, kindly donated by Vector Instruments. This device will eventually be hooked into the new, upgraded, weather station module that I am designing. The current prototype is producing live data here: http://www.goatindustries.co.uk/weather/ .

Comparing this sensor to my DIY Digital Wind Vane the first thing I noticed was the extreme sensitivity to wind movement - it has very low torque - so it is able to pick up wind direction even in very small wind speeds. Secondly, being made on a CNC lathe, the quality of the engineering is superb - I really must get myself a CNC lathe!

Here, I am going to show how I set up and coded an arduino to read the sensor, made calculations for non-linearity, took account of the 'dead zone' in the potentiometer, turned the readings into a large numerical array, efficiently calculated the mode value and made the whole device self calibrating. No pressure!

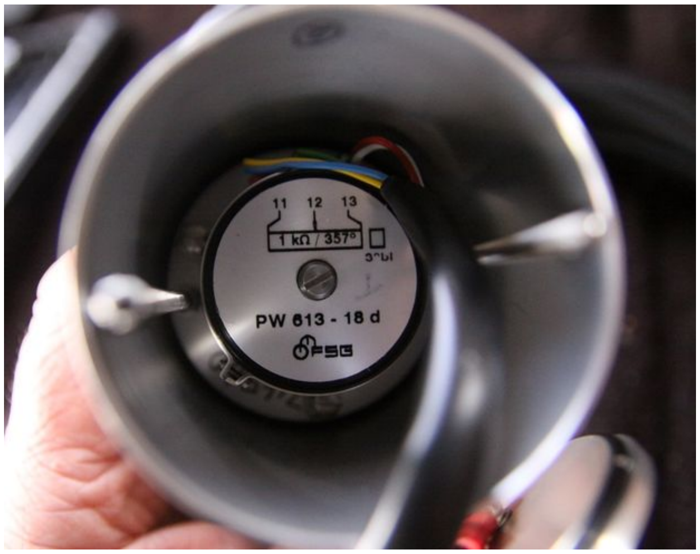


Step 1: How it Works

This analogue wind vane is based on a very expensive potentiometer with three main connections - 5V, ground and wiper. The wiring inside the deice is very thin so great care is needed not to put too much current through the circuits for too long or it could quite easily get burnt out.

I have protected the wiper part of the circuit with a 10k resistor which feeds a signal to the arduino via pin A0. This is then converted into a digital 10 bit code inside the processor with a full range of 0 to 1024. The device is never fed a continuous supply of power and is pulsed in two different ways. Firstly, there is a load of really fast 50 millisecond pulses which gets us 10 readings at a time, next the whole device goes off for 1/2 a second until the next batch of readings is made. By working out an average (mean), we end up with one fairly accurate reading per second.

So now that we've got this digital reading - what else could be simpler? Surely that's the end of it?



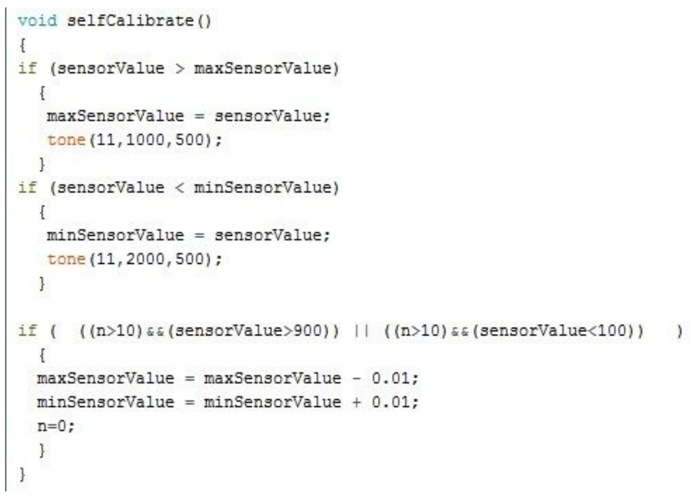
Step 2: Project Challenges and Solutions

Firstly, when working with analogue to digital conversion in the past, I have noticed significant 'drift' around minimum and maximum values and so some code is going to need to be written to counteract this phenomenon. Secondly, wind can sometimes be extremely turbulent which makes it very difficult to get an accurate output value. If the wind was constantly changing from, say, south to west we would want to process our data in such a way that it would give the most common direction, not just the average or 'mean', otherwise we would just get a value of south-west. To explain in more detail - the wind might veer from south to west and back again, but actually it's mostly coming from the south-south-west. If this is beginning to hurt your brain cells, I totally sympathise!

Fortunately we have solutions to both the above problems - we take as many readings as the system memory and speed will allow and build some truly massive arrays of numbers. We then make a continuous log of the number of times each part of the array is hit and then, finally, spit out the most popular. In the digital wind vane project I wrote some rather clunky code for calculating the 'mode' value and now, with the power of some extra nutritious coffee granules, I have reduced that code to something rather more sublime!

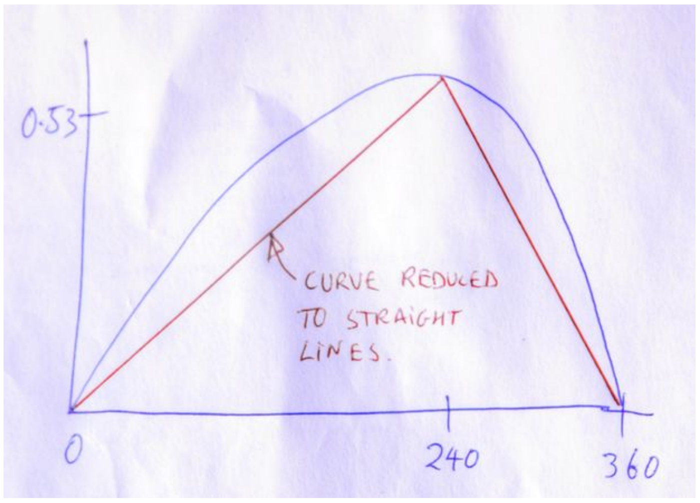
Finally, after about ten minutes, just when our arrays are about to explode the arduino into a million fragments of silicon dust, we retrieve a single wind direction value eg 215 with a second arduino and reset all the large numbers to zero.

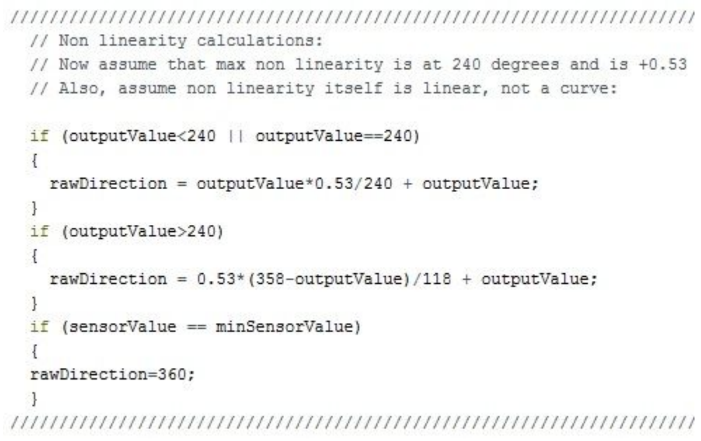
Now that we're beginning to feel quite glib about our engineering prowess, the analogue wind vane chucks at us 2 more major problems - ONE: it does not produce a true linear output and TWO: it has a dead zone around the north pole of about 3 degrees. At first, my brain cells started to panic at the prospects of solving the non linearity problem but then they remembered that wind is always slightly turbulent so the question arose: How accurate do we really need to be? Do we really need to look into a lot of detail at the non linearity curve? Common sense then came to the rescue and the curve got chopped and straightened into 2 simple straight lines, with an apex at 240 degrees. Simple!



```
void selfCalibrate()
{
if (sensorValue > maxSensorValue)
  {
   maxSensorValue = sensorValue;
   tone(11,1000,500);
  }
if (sensorValue < minSensorValue)
  {
   minSensorValue = sensorValue;
   tone(11,2000,500);
  }

if (  ((n>10)&&(sensorValue>900)) || ((n>10)&&(sensorValue<100))   )
  {
  maxSensorValue = maxSensorValue - 0.01;
  minSensorValue = minSensorValue + 0.01;
  n=0;
  }
}
```





```
/////////////////////////////////////////////////////////////////////
  // Non linearity calculations:
  // Now assume that max non linearity is at 240 degrees and is +0.53
  // Also, assume non linearity itself is linear, not a curve:

  if (outputValue<240 || outputValue==240)
  {
    rawDirection = outputValue*0.53/240 + outputValue;
  }
  if (outputValue>240)
  {
    rawDirection = 0.53*(358-outputValue)/118 + outputValue;
  }
  if (sensorValue == minSensorValue)
  {
  rawDirection=360;
  }
/////////////////////////////////////////////////////////////////////
```

Step 3: Parts

1. C1 Electrolytic Capacitor package 100 mil [THT, electrolytic]; voltage 6.3V; capacitance 1µF
2. J1 Piezo Speaker
3. LED1 Green (560nm) LED package 5 mm [THT]; leg yes; color Green (560nm)
4. Part1 Arduino Nano (Rev3.0) type Arduino Nano (3.0)
5. R1 100O Resistor resistance 100O; package THT; bands 4; tolerance ±5%; pin spacing 400 mil
6. R2 2kO Resistor resistance 2kO; package THT; bands 4; tolerance ±5%; pin spacing 400 mil
7. R3 10kO Resistor resistance 10kO; package THT; bands 4; tolerance ±5%; pin spacing 400 mil
8. R5 100kO Resistor resistance 100kO; package THT; bands 4; tolerance ±5%; pin spacing 400 mil
9. S1 Pushbutton package [THT]
10. W200P wind vane from Vector Instruments

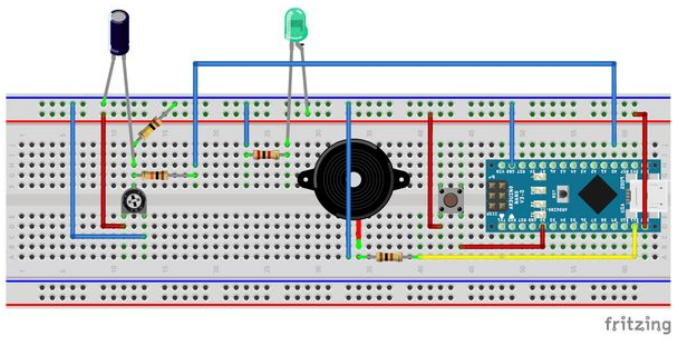
Step 4: Arduino Setup

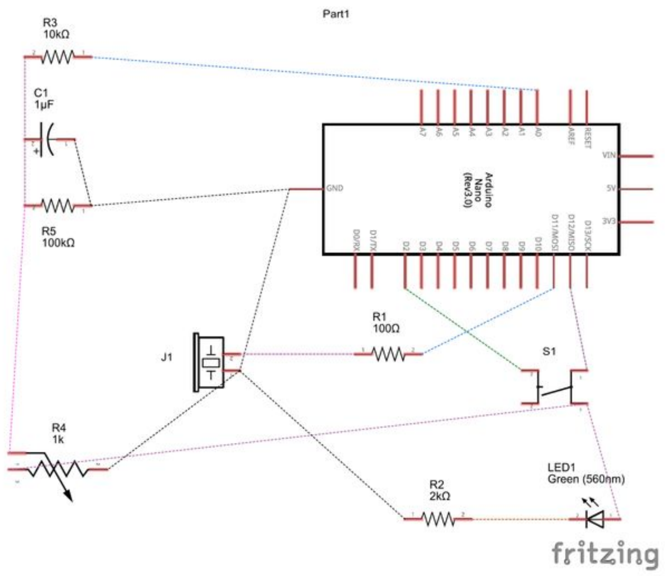
This is the easy and fun part and we can make lots of reassuring beeping noises and flickering of LEDs to make us feel better after having brutalised our brain cells so much in the previous steps. The LED flickers because the power supply is being pulsed and the micro speaker beeps when we have got the wind vane in the self calibration zone.

After wiring up the breadboard, we connect the power and point the wind vane to due north, which will be in the dead zone. We then move the vane very slightly to the left and right and there should be beeping noises produced in two separate audio frequencies, representing minimum and maximum range settings being discovered. Do this a couple of times and the sensor is calibrated and remains calibrated until the power is disconnected.

As time goes on, but only when the wind is blowing roughly from the north, the maximum calibration setting is very slowly decreased, or pulled back, until it is over-ridden by a new setting. The same happens with the minimum setting, but in the opposite direction, i.e. pushed forwards.

I did also play about with the capacitor on the wiper pin and found that a 1 micro farad capacitor was better than the 10 nano farad proscribed in the data sheets. Please don't ask me why this value is better as I don't really know! I just noticed less 'spurious' readings in the serial monitor when the sensor was coming in and out of the dead zone.





Step 5: Code

```
const int analogInPin = A0;  // Analog input pin that the potentiometer is attached to
const int analogOutPin = 9; // Analog output pin that the LED is attached to
const int tonePin = 11;
int sensorValue = 1;
float outputValue = 0;
float rawDirection =0;
float maxSensorValue =980.9999;
float minSensorValue = 5.0001;
int finalDirection=0;
int biggestAddingDirection=0;
int z=0;
int sensorValue2=0;
int n=0;
int modeSize=0;
int c=0;
int degree =0;
int addingDirection[]=
 {1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,
 40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,
 80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106,107,108,109,110,111,112,113,114,115,116,117,118,119,
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 240,241,242,243,244,245,246,247,248,249,250,251,252,253,254,255,256,257,258,259,260,261,262,263,264,265,266,267,268,269,270,271,272,273,274,275,276,2
 280,281,282,283,284,285,286,287,288,289,290,291,292,293,294,295,296,297,298,299,300,301,302,303,304,305,306,307,308,309,310,311,312,313,314,315,316,3
 320,321,322,323,324,325,326,327,328,329,330,331,332,333,334,335,336,337,338,339,340,341,342,343,344,345,346,347,348,349,350,351,352,353,354,355,356,3

void setup()
{
 pinMode (12,OUTPUT);          // This provides short pulses of power to the sensor from pin 12.
 pinMode (13,OUTPUT);
 pinMode(2, INPUT_PULLUP);
 digitalWrite(13, LOW);
 Serial.begin(9600);
 while (degree<362)            // Set all 362 values to zero.
 {
   addingDirection[degree] = 0;
   degree++;
 }
 maxSensorValue =984.9999;
}

void loop()
{
 resetValues();
 z=0;
 n++;
 sensorValue2=0;

 while (z<10)                              // Get 10 quick readings.
   {
   z++;
   digitalWrite(12, HIGH);
   delay(5);
   // read the analog in value:
   sensorValue = analogRead(analogInPin);
   sensorValue2 = sensorValue2 + sensorValue;
   digitalWrite(12, LOW);
   delay(45);
   }

 delay(500);                             // set this to 500 so total delay = 1 second.
 sensorValue = (sensorValue2/z);
 // assume that dead band starts at 356.5 and ends at 0
 // and values of zero correspond to 360 or 0 degrees:
 // The maximum analogue reading I am getting on the wiper is 981
 // out of a possible range of 1024 (10 bits)

 if (sensorValue == 0)
 {
   outputValue =0;
 }

 outputValue = ((sensorValue-minSensorValue)*356.5/maxSensorValue)+1.75;

 selfCalibrate();                         // Checks the maximum range of the analoue readings when sensor comes out of dead band.

//////////////////////////////////////////////////////////////////////////////////////////////////////////
 // Non linearity calculations:
 // Now assume that max non linearity is at 240 degrees and is +0.53
 // Also, assume non linearity itself is linear, not a curve:

 if (outputValue<240 || outputValue==240)
 {
   rawDirection = outputValue*0.53/240 + outputValue;
 }
 if (outputValue>240)
 {
   rawDirection = 0.53*(358-outputValue)/118 + outputValue;
 }
 if (sensorValue == minSensorValue)
 {
 rawDirection=360;
 }
////////////////////////////////////////////////////////////////////////////////////////////////////////
 Serial.print("sensor = ");
 Serial.print(sensorValue);
 Serial.print("\t output = ");
 Serial.print(outputValue,2);
 Serial.print("\t adjusted output = ");
 Serial.print(rawDirection,2);
 Serial.print("\t Max sensor value = ");
 Serial.print(maxSensorValue,2);
 Serial.print("\t Min sensor value = ");
 Serial.print(minSensorValue,2);
 Serial.print("\t n = ");
 Serial.println(n);

 digitalWrite(12, LOW);

degree = (int)rawDirection;

/////////////////////////////////////////////////////////////////////////////////////
// Special case for rawDirection = 360:
if (rawDirection ==360)
{
 degree = 359 + c;
 c++;
}
if (c>2)
{
 c=0;
}
if (degree==361)
{
 degree=1;
}
///////////////////////////////////////////////////////////////////////////////////////
// Calculate the running mode (Some of these variables will need to be reset by a call back from main processor).

addingDirection[degree] = addingDirection[degree] +1;
if (addingDirection[degree] > modeSize)
{
 modeSize = modeSize +1;
 finalDirection = degree;
}

////////////////////////////////////////////////////////////////////////////////////////
if (finalDirection==359 || finalDirection==360 || finalDirection==1)
{
 finalDirection=360;
}
 Serial.print("Mode size = ");
 Serial.print(modeSize);
 Serial.print("\t Degree = ");
 Serial.print(degree);
 Serial.print("\t Final Mode Direction = ");
 Serial.print(finalDirection);
 Serial.print("\t Adding direction[degree] = ");
 Serial.println(addingDirection[degree]);

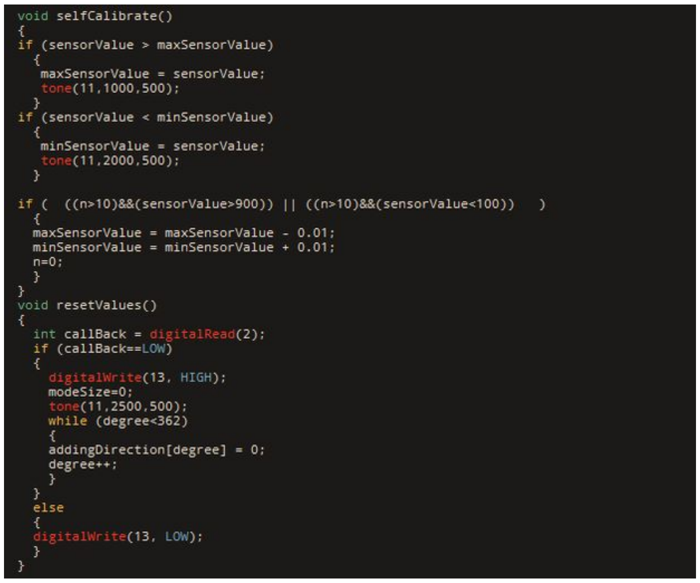
 Serial.println("");

}
// 30 days = 2592000 seconds
// Each loop of n x 10 is ten seconds
// Every ten seconds max sensor value is reduced by 0.0001
// Every 30 days max sensor values reduced by 2592000 / 10 * 0.00001 = 25.92 degrees
// In 3 days of northerly winds max sensor value will adjust by as much as 2.592 degrees.
// During northerly winds the sensor will self calibrate:

void selfCalibrate()
```

```
{
if (sensorValue > maxSensorValue)
 {
  maxSensorValue = sensorValue;
  tone(11,1000,500);
 }
if (sensorValue < minSensorValue)
 {
  minSensorValue = sensorValue;
  tone(11,2000,500);
 }

if (  ((n>10)&(sensorValue>900)) || ((n>10)&(sensorValue<100))   )            // Only adjust min and max sensor readings in a northerly wind.
 {
 maxSensorValue = maxSensorValue - 0.01;                                       // Slowly pulls back max sensor value.
 minSensorValue = minSensorValue + 0.01;                                       // Slowly pushes forwards min sensor value.
 n=0;
 }
}
void resetValues()                                   // Requires a call back pulse of 5 seconds to reset key values.
{
 int callBack = digitalRead(2);
 if (callBack==LOW)
 {
   digitalWrite(13, HIGH);
   modeSize=0;
   tone(11,2500,500);
   while (degree<362)
   {
   addingDirection[degree] = 0;
   degree++;
   }
 }
 else
 {
 digitalWrite(13, LOW);
 }
}
```



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   tone(11,2000,500);
  }

if (  ((n>10)&&(sensorValue>900)) || ((n>10)&&(sensorValue<100))   )
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  }
}
void resetValues()
{
  int callBack = digitalRead(2);
  if (callBack==LOW)
  {
    digitalWrite(13, HIGH);
    modeSize=0;
    tone(11,2500,500);
    while (degree<362)
    {
    addingDirection[degree] = 0;
    degree++;
    }
  }
  else
  {
  digitalWrite(13, LOW);
  }
}
```

Step 6: Final

This sensor is quite different from the digital wind vane that I built myself. It works approximately ten times better in very light winds and it's smaller and infinitely more robust. The calibration aspect does create a bit of a question mark in my mind but this could well be down to my own bad circuit design or even bad wiring. Spurious readings could also be produced by the serial port circuits themselves, through which I am observing the data. In some respects, the digital wind vane is better - it never needs calibrating and there is no dead zone at north. There are, however, tiny dead zones between each individual 'bits' of data and there's so much torque needed to drive the rotary encoder that the vane has to be big and subsequently ugly. I did research other rotary encoders, but they all seem to have similar torque ratings.

There is an easy way to remove the dead zone from this sensor by doubling up on the potentiometer machinery - one pot piggy backed on the other and offset by 90 or 180 degrees - but this would double the torque required and make the device more expensive. Coding would be fairly easy as the second pot would only be used during the dead zone and we already know where the dead zone starts and ends. The electronics that I have been using could even be pre-programmed and slotted into the W200P housing itself, giving a simple digital quadrature or grey code output or PWM frequencies.

Although I love the thought of being able to build my own sensors, I have the greatest of respect for the provenance of this commercial one - it has been used in the most severe conditions for over 40 years, so will be replacing the DIY digital one at the earliest opportunity!

Coming next .... Setting up the Vector Instrument's wind speed sensor .... Watch this space!

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