

# ESD\_2

*by* Matt Russell

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# Electronic Systems Design 2

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## Abstract

This report covers the design of a portable amateur meteorological station capable of measuring over a 14-day period. The station will measure the following:

- Temperature
- Humidity
- Wind Speed
- Wind Direction
- Airborne particle count
- Sunlight brightness
- UV levels
- GPS position
- VOC level

The report will include a brief literature review covering a selection of sensors for each feature being measured highlighting the selected sensor and briefly justifying the selection. Also included is the selection and justification of a microcontroller, casing, storage size (non-volatile memory). A PCB design, which uses both Proteus [1] and Easy-PC [2] design suite, will also be included along with a software design structure for the PIC and build costs. The report will be completed by providing a list of improvements for next iterations of the design.

## Literature Review

The purpose of this literature review is to look at already on the market weather stations to gather and understanding how they operate as well as comparing and contrasting the different stations available. A selection of four weather stations were selected which could at least measure wind speed and direction humidity and precipitation. Additional measurements such as UV and air pressure could also be available on some of the models.

| Weather Station                        | Picture                                                                             | Measurement                                                                             | features                                                                                                                            | Cons                                         | Price   | Ref |
|----------------------------------------|-------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|---------|-----|
| ACCUR8 DWS7100 (outdoor wireless unit) |    | Rain, light, UV, wind speed, wind direction, temperature, humidity                      | Weather Console, Wi-Fi connection, Good measurement ranges, Solar Powered.                                                          | Up-to 24hr memory,                           | £149.95 | [3] |
| Tempest Weather System                 |    | Ambient <u>Light</u> , <u>UV</u> , Solar, Temp, <u>Humidity</u> , Wind, Rain, lightning | Smart home compatible, Used through tempest app                                                                                     | Little info available                        | £349.00 | [4] |
| National Geographic 9080500            |   | Temp, wind speed & direction, air pressure, precipitation                               | 3AA battery supply, Display console included, 24hr memory for some features such as air pressure                                    | Only 5 sensors, little information available | £143.95 | [5] |
| Davis Wireless Vantage Pro 2           |  | Barometric pressure, temperature, humidity, rainfall, wind speed & direction and UV.    | Solar Powered, 0.14mA current draw, External Console, up to 21 parameters, Can connect to mobile with Wi-Fi, Access to a community, | Expensive                                    | £995.00 | [6] |

Figure 1: Weather Stations available on the market

## Microcontroller

The PIC18F46K22 [7] is an 8-bit microprocessor with a max clock speed of 64MHz, 3.8KB of RAM and a 16 channel 10-bit Analogue to Digital Converter (ADC). Like with many PICs it takes 4 clock cycles to execute an instruction making the instruction cycle rate 16MHz, a speed still very capable with dealing data rates expected from the sensor readings. The PIC has an operating voltage range of 1.8- 5.5V with a total of 44 pins. This PIC also offers 2 Universal Asynchronous Receive Transmit (UART) communication pins and 2 dual Serial Peripheral Interface (SPI) and Inter-Integrated Circuit (I2C) communication pins. The PIC18F46K22 [7] is fully compatible with C programming language which will make it easier to configure the software for the weather station.

After final selection of the sensors it was determined that the PIC would need to be able to accommodate 6 analogue inputs, 2 UART and 1 I2C inputs. A further SPI pins would be required for the SanDisk (SD) card connector and another UART connection for the USB. However, as the UART pins were already being used a MCP2221A [8] breakout board was used to convert serial to I2C which enabled no major re-configuration of the embedded system at no real additional cost with the breakout board only costing £6.30 [8]. For the analogue inputs the 10-bit ADC would provide good resolution of analogue inputs to get a good digital representation of them.

Additional hardware will also be needed for the air particle sensor to accommodate RS-485 communication protocol. The EUSART module on the PIC18F46K22 [7] does not directly support RS-485 [9] because the protocol is based of differential signalling concept. However, the PIC does provide the correct UART pins and a GPIO (General Purpose Input Output) pin can be used as the Driver Enable (DE) pin also required for this protocol. The sensor recommends the use of a pmodRS4985 [10] module which is compliant with the RS-485 differential signalling and converts the dual signalling to single ended Transistor-Transistor Logic (TTL). Which is the format applicable with the microcontroller.

Furthermore, the PIC18F46K22 [7] can run off a 5V power supply with all the sensors and other peripherals able to operate on 5V or 3.3V. Therefore, with the use of a LM317 [11] voltage regulator all the components can be run off the same power supply.

The 64MHz clock speed matched with 3.8KB of RAM is well within the PIC18F46K22 capability of being able to read in sensor inputs. All digital interfaces can be read in 1 instruction cycle (4 clock cycles) whereas the ADC takes a bit longer taking at least 2 instruction cycles to trigger and read the ADC result but also must include the ADCs conversion time which is the time taken to read the signal. However, this is all within the PIC18F46K22 [7] ability and so not a problem seeing as the fastest a sensor is read on this system is every 2 seconds.

## Casing, Connectors & Sensors

### Casing

The casing needed to be large enough to accommodate the PCB, battery, connectors and internal wiring. The external sensors will be connected via a connector side board shown in figure 2. The panel is 165mmx115mm and accommodates 6 connection ports [12]. This is because the GPS sensor will be housed inside the casing as the plastic should not disrupt the connection significantly to deny a GPS connection. In practice, the connection points are likely to be cut outs and sealed with silicon to maintain waterproofness. The “1200 Protector” Peli-case [13] will be used as the case as it has a strong IP rating of IP67 [14] meaning it can withstand water jets. Furthermore, it is large enough to house all the components with internal dimensions of 241 x 185 x 105mm as well as the connections on the side of the case with exterior dimensions of 270 x 246 x 124mm [13].



*Figure 2: Mock-up of the connector panel on the side of the casing [12]*



Figure 3: Peli-case Protector 1200 [13]

### Storage

The storage requirements for this weather station are very low at 8MB. The reason for this is the reading frequency from the majority of sensors is very slow and the byte requirement per reading is small. The byte requirement per reading is as follows:

- Temperature – 2 bytes every 60 seconds
- Humidity – 2 bytes every 60 seconds
- Wind Speed – 3 bytes every 2 seconds
- Wind Direction – 2 bytes every 2 seconds
- Ambient Light – 2 bytes every 60 seconds
- UV – 2 bytes every 60 seconds
- VOC – 2 bytes every 60 seconds
- Airborne Particles – 6 bytes (2 bytes per particle type, RS485 [9]) every 60 seconds.
- GPS – 80 bytes (National Marine Electronic Association (NMEA) 0183 protocol [15]) every hour.

The PIC18F46K22 [7] has a 10-bit ADC so all analogue sensors will be a minimum of 2 bytes in size. The only exception to this is the anemometer which due to it being voltage pulsed and having a resolution of 0.1m/s and a range of 1-67m/s requires 3 bytes to get the resolution at this measurement range. The ambient light sensor uses I2C protocol to send the readings to the PIC which are 16-bits long also (2 bytes). The Airborne particle sensor

uses UART and measures 3 types of particle matter types: PM10, PM2.5 & PM1. Each of these readings require 2 bytes and so a total of 6 bytes is needed. GPS uses the NMEA 0183 protocol to communicate which transmits data in 'sentences'. To get a time, position and fix related data is done through the GPGGA sentence which is 86 bytes long [15].

\$GPGGA,172814.0,3723.46587704,N,12202.26957864,W,2,6,1.2,18.893,M,-25.669,M,2.0 0031\*4F

Figure 4: GPS GPGGA sentence example [15]

The frequency at which these sensors were taken was based upon how frequently the phenomenon measured will update. It was determined wind speed and direction change most frequently as gusts and then the associated wind change direction can come on quick and be short in duration. Furthermore, it is useful to know how strong and frequent gusts are as this can determine how dangerous the weather is [16]. Temperature and humidity do not change as quickly and speed and direction and so do not need to be updated as quickly. As per the World Meteorological Office (WMO) a 1 – 10-minute interval is suitable for measuring temperature and humidity [17]. Ambient light and UV will be similar to temperature and humidity as changes in UV and lighting would only change drastically due sporadic cloud cover. Therefore 60 seconds was determined suitable for these sensors too. The same interval was applied to VOC and air particle so any dangerous particles can be detected quickly.

A 128 GB SD card was selected to store this data as in terms of pricing there was no major difference in something of smaller storage with the SD only costing £8.90 [51].

| Sensor          | rep time (s) | Bytes per reading | bytes/60    |
|-----------------|--------------|-------------------|-------------|
| Temp/Humid      | 60           | 5                 | 120         |
| Spd & Dir       | 2            | 4                 | 240         |
| Air Particles   | 60           | 6                 | 6           |
| GPS             | 3600         | 80                | 0.022222222 |
| UV              | 60           | 2                 | 2           |
| Amb Light       | 60           | 2                 | 2           |
| VOC             | 60           | 2                 | 2           |
| Total bytes 60s |              |                   | 372.0222222 |
| in 1hr          |              |                   | 22321.33333 |
| in 14 days      |              |                   | 7499968     |
| in MB           |              |                   | 7.499968    |

Figure 5: Storage Requirements

## Sensors

The following table highlight different types of sensor for each variable being measured providing a short summary of the advantages and disadvantages of each one.

| Humidity   | Advantages                                                                                                | Disadvantages                                                             |
|------------|-----------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------|
| Capacitive | Linear Voltage,<br>Low Cost,<br>Stable Results,<br>Little Maintenance,                                    | Distance Limitations,<br>Loss of relative humidity <5%                    |
| Resistive  | Low Cost,<br>Small Footprint,<br>No Calibration,<br>No real distance limitations as with capacitive type. | Sensitive to Contaminants,<br>Not optimal for RH < 5%.                    |
| Thermal    | Very Resistant,<br>Used in high temp environment,<br>suitable against corrosion.                          | Humidity readings affected when exposed to gases with thermal properties. |

Figure 6: Humidity Sensor Types [18]

| Temperature         | Advantages                                                                                        | Disadvantages                                                                                                   |
|---------------------|---------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------|
| Resistive           | Low Cost,<br>High Accuracy,<br>High Repeatability,<br>Wide operating range                        | Not used above 660C,                                                                                            |
| Thermocouples       | Greatest temperature range of any other type a sensor,<br>Best performers in extreme temperatures | Slowly replaced by resistive types,<br>Non-linear so need conversion tables,<br>Low accuracy between 0.5C to 5C |
| Semiconductor Based | Linear response,                                                                                  | Low accuracy,<br>Slowest Response,<br>Narrowest temperature ranges.                                             |

Figure 7: Temperature Sensor Types [19]

| Anemometer | Advantages                                                                | Disadvantages                                                            |
|------------|---------------------------------------------------------------------------|--------------------------------------------------------------------------|
| Rotating   | Linear voltage,<br>Low cost                                               | Moving components can get stuck,<br>Can be susceptible to dirt and dust. |
| Ultrasonic | No Moving Parts,<br>Very Durable                                          | Complex,<br>Higher cost                                                  |
| Thermal    | No Moving Parts,<br>Durable,<br>Suitable for low wind speed measurements. | Easily affect by the ambient temperature<br>Expensive.                   |

Figure 8: Anemometer Sensor Types [20]

| Wind Direction | Advantages                                                             | Disadvantages                                                                                                    |
|----------------|------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------|
| Rotating       | Durable & reliable,<br>Cost effective,<br>Easy to maintain             | Prone to wear and tear,<br>Prone to environmental factors                                                        |
| Ultrasonic     | High accuracy,<br>No moving parts,<br>Can operate in all-weather types | High cost,<br>Prone to environmental factors<br>Require stable power sources                                     |
| Thermal        | No moving parts,<br>High accuracy,<br>Compact and lightweight          | Limited working range,<br>Higher energy requirements for<br>heating element,<br>Sensitive to temperature changes |

Figure 9: Wind Direction Sensor Types [21]

| UV         | Advantages                                                           | Disadvantages  |
|------------|----------------------------------------------------------------------|----------------|
| Photodiode | Fast Response times,<br>Sensitive when detecting low light<br>levels | More Complex   |
| Photocell  | Lower response times,<br>Simpler,<br>Less Expensive                  | Less Sensitive |

Figure 10: UV Sensor Types [22]

| VOC                                   | Advantages                                                           | Disadvantages                                                                |
|---------------------------------------|----------------------------------------------------------------------|------------------------------------------------------------------------------|
| Photoionisation<br>Detectors (PID)    | High sensitivity,<br>Broad Range,<br>Portable<br>Non-destructive     | Selective response,<br>UV lamp maintenance,<br>Response effected by humidity |
| FIDs                                  | Wide sensitivity,<br>Robust against interference,<br>Linear response | Complex,<br>Require calibration,<br>Destructive testing                      |
| Metal Oxide<br>Semiconductor<br>(MOS) | Low Cost,<br>Simple,<br>Durable                                      | Lower Sensitivity,<br>Non-Specific detection                                 |

Figure 11: VOC Sensor Types [23]

| <b>Airborne Particle</b> | <b>Advantages</b>                                                                                                   | <b>Disadvantages</b>                                                                                                                                 |
|--------------------------|---------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------|
| Infrared                 | Simple infrastructure,<br>Cost effective,                                                                           | Cannot differentiate particles,<br>Affected by environmental factors,<br>Less reliable for professional applications                                 |
| Beta Attenuation         | Very high accuracy,<br>Able to differentiate particles,<br>Good at long term monitoring                             | Very expensive,<br>Requires accurate calibration,<br>Complex infrastructure,<br>Results sensitive to variations                                      |
| Optical                  | Good sensitivity,<br>Large dynamic range,<br>Immune to electromagnetic interference,<br>Suitable for remote sensing | Environmental factors can affect measurements,<br>Can be costly,<br>Can be fragile,<br>Limited ability in differentiating particle type and/or size. |

Figure 12: Airborne Particle Sensor [24]

| <b>Ambient Light</b> | <b>Advantages</b>                                                              | <b>Disadvantages</b>                   |
|----------------------|--------------------------------------------------------------------------------|----------------------------------------|
| phototransistors     | Versatile,<br>Higher current output                                            | Slow response times,<br>Larger in size |
| Photodiode           | Durable,<br>High sensitivity,<br>Low power consumption,<br>Fast Response times | Limited Range,<br>Low current output   |
| Photonic ICs         | High functionality,<br>High Precision,<br>Reduced size                         | More Expensive,<br>Greater complexity  |

Figure 13: Ambient Light Sensor Types [22]

| Temp & Humidity                                                                   | Sensor                                             | comms (Type)            | Price (£) | pin | Accuracy                      | Temp Range °C | Voltage (V)          | Current (A)     |
|-----------------------------------------------------------------------------------|----------------------------------------------------|-------------------------|-----------|-----|-------------------------------|---------------|----------------------|-----------------|
|  | TE Connectivity Temperature & Humidity Sensor      | None /DC voltage Analog | £119.08   | 5   | humid +/- 2%<br>temp +/- 1%   | - 40 to 85    | 5, max 12            | <u>uA</u> (neg) |
|  | AM2315C Humidity and Temperature Module            | I2C                     | 20.89     | 4   | humid +/- 2%<br>temp +/- 0.3% | -40 to 85     | 2.2- 5.5 (3 typical) | <u>uA</u> (neg) |
|  | HTM2500LF Temperature and Relative Humidity Module | none/ DC voltage        | 137.84    | 5   | humid +/- 2%<br>temp +/- 1%   | -40 to 80     | 5, max 12            | <u>uA</u> (neg) |
|  | SHT21-TR-0.4KS                                     | I2C                     | 1,247.72  | 6   | humid 0.04%<br>Temp 0.001C    | -40 to 125C   | 3 max3.6             | <u>uA</u> (neg) |

Figure 14: List of Humid & Temperature sensors [25] [26] [27] [28]

Capacitive and resistive type sensors were chosen for the humid and temperature sensors respectively. These types were selected as they were relatively low cost and provided suitable performance for the task. Furthermore, these types were easily accessible and readily available for purchase with sensor types offering dual functionality which would make the PCB design simpler. As seen in figure 14 the TE Connectivity Temperature & Humidity sensor [25] was selected as it provided a desirable performance at the best cost whilst being easily interactable with the PCB.

| Wind Speed & Direction                                                             | Sensor                                      | comms (Type)       | Price (£) | pin                     | Accuracy                                       | Temp Range °C | Voltage (V) | Current (mA) |
|------------------------------------------------------------------------------------|---------------------------------------------|--------------------|-----------|-------------------------|------------------------------------------------|---------------|-------------|--------------|
|   | Anemometer & wind direction [Pro-D]         | pulsed voltage     | £239      | 4                       | dir $\pm 7^\circ$<br>deg<br>spd 2%             |               | max 12      | max 100      |
|   | Poly-carbon Wind Speed and Direction Sensor | Analog/ SPI/ RS485 | 68.18     | unknown                 | 0.3                                            | 30 to 70      | 5 to 24     | 4 to 20      |
|   | Wind Speed & Direction Sensor AV-WSD        | pulsed voltage     | 1,250     | 6                       | is $\pm 2\%$                                   | -20 to 70     | 100         | 1000         |
|  | WSD-V Wind Speed & Direction Sensor         | pulsed voltage     | 460       | 4 pin to interface unit | dir $< 1^\circ$<br>deg<br>spd $< 0.5\text{ms}$ | -20 to 60     | 24          | 50 max       |

Figure 15: Wind Speed & Direction Sensors [29] [30] [31] [32]

Rotating reed contacts and potentiometer sensors were chosen for the wind speed and wind direction respectively. These types were selected as they offered the accuracy required by the task whilst also being cost effective and easy to implement with the PCB.

| Airborne Particle Count                                                           | Sensor                                                                  | comms (Type)   | Price (£) | pin | Accuracy      | Temp Range °C | Voltage (V) | Current (mA)                    |
|-----------------------------------------------------------------------------------|-------------------------------------------------------------------------|----------------|-----------|-----|---------------|---------------|-------------|---------------------------------|
|  | TERA Sensor Next-PM, Particle Matter / Dust Air Quality Sensor, Optical | RS485/ UART    | 81.89     | 6   | 0.3 to 1 um   | -20 to 70     | 5 -3.3      | <80 (max 300) <20 in sleep mode |
|  | SEN5x Environmental Sensor Node for HVAC and Air Quality Applications   | I2C            | 21.05     | 6   | 0- 1000ug/m^3 | -10 to 50     | 5           | 4.2 max                         |
|  | Omron B5W-LD0101-1, Air Quality Sensor                                  | pulsed voltage | 10.72     | 5   | 0.5um         | 0 to 45       | 5 (5.5max)  | max 90 mA                       |

Figure 16: Airborne Particle count Sensor [33] [34] [35]

The optical sensor type was selected as the airborne counter type as it offered good accuracy and wide range being able to read PM10, PM2.5, PM1 with PM1 being 1.0 microns thick. The optical type also appeared to be the most available and able to meet the requirement of the task and easily implemented with the PCB.

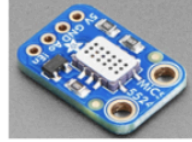
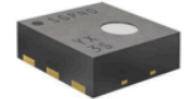
| VOC                                                                                 | Sensor                                         | comms (Type)      | Price (£) | pin | Accuracy                           | Temp Range °C  | Voltage (V)   | Current (mA) |
|-------------------------------------------------------------------------------------|------------------------------------------------|-------------------|-----------|-----|------------------------------------|----------------|---------------|--------------|
|  | VOC Sensor Module, MQ138                       | Analog and/or TTL | 109.75    | 4   | 5-500ppm                           | minus 10 to 50 | 5             | 150          |
|  | Youmile 1 pcs MiCS5524 CO Alcohol and VOC Gazi | analogue          | 10        | 4   | 1-1000,1-500 dependent on particle | minus 30 to 85 | 5             | 25-35        |
|  | SGP40 VOC                                      | I2C               | £3.29     | 6   | 0-500                              | minus 10 to 50 | 3.3 (max 3.5) | 2.6-3        |

Figure 17: VOC sensors [36] [37] [38]

The VOC sensor was the most difficult to find as there seemed to be many but few that could be integrated with a PCB easily. It seemed the MOS type was most suitable to integrate with the PCB however this was at the expense of accuracy as MOSs cannot

differentiate between compounds. However, as there was no requirement for this and was therefore suitable for the system.

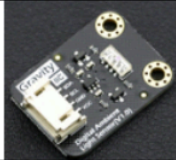
| Ambient Light                                                                     | Sensor                                                                            | comms (Type) | Price (£) | pin | Accuracy (lx) | Temp Range °C | Voltage (V)   | Current (mA) |
|-----------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|--------------|-----------|-----|---------------|---------------|---------------|--------------|
|  | SEN0390 DFRobot, Ambient Light Sensor                                             | I2C          | 9         | 5   | 0.054         | -40 to 85     | 2.7-6         | 0.7          |
|  | SEN0228                                                                           | I2C          | 7.8       | 4   | 0.0036        | -20 to 80     | 3.3-5         | 45uA (neg)   |
|  | VEML7700-TT Vishay, Ambient Light Sensor, Ambient Light to Digital Data I2C 4-Pin | I2C          | 1.01      | 4   | 0.0042        | -25 to 80     | 3.3 (2.7-3.6) | 0.045        |

Figure 18: Ambient Light Sensors [39] [40] [41]

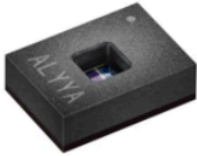
| UV light                                                                            | Sensor                                                    | comms (Type) | Price (£) | pin | Accuracy (nm) | Temp Range °C | Voltage (V) | Current (mA) |
|-------------------------------------------------------------------------------------|-----------------------------------------------------------|--------------|-----------|-----|---------------|---------------|-------------|--------------|
|  | AS7331-AQFM ams OSRAM, UV Light Sensor, I2C 16-Pin OLGA16 | I2C          | 12.35     | 16  | 240- 430      | - 40 to 85    | 3.3, max5   | 1.42, max 2  |
|  | Waveshare UV Sensor                                       | analogue     | 3.12      | 3   | 200-370       | -30 to 85     | 2.7-5.5     | max 1uA neg  |
|  | Groove UV Sensor                                          | analogue     | 10.90 \$  | 4   | 200-370       | -30 to 85     | 2.7-5.5     | max 1uA neg  |

Figure 19: UV light sensors [42] [43] [44]

Photodiodes were selected to be the sensor type on the ambient as well as for the UV sensor as they offered high sensitivity and durability whilst still being very cost effective [39].

| Sensor Type (GPS)                                                                   | Sensor                                                | comms (Type)        | Price (£) | pin | Accuracy | Temp Range °C | Voltage (V)              | Current (mA) |
|-------------------------------------------------------------------------------------|-------------------------------------------------------|---------------------|-----------|-----|----------|---------------|--------------------------|--------------|
|    | GPS receiver module                                   | USB/RS485?          | 10.94     | 5   | unknown  | unknown       | <a href="#">3.6 to 5</a> | unknown      |
|    | GY-NEO6MV2<br>GY-NEO7MV2                              | RS232               | 0.65      | 4   | unknown  | 0-85          | 3 to 5                   | unknown      |
|   | Gravity: GNSS GPS BeiDou Receiver Module - I2C & UART | UART & I2C          | 18        | 4   | 2m       | -40 to 80     | 3.3 to 5                 | 40           |
|  | GARMIN                                                | serial (RS 232)-USB | 102.56    | 3   | <3m      | -30 to 80     | 4-5.5                    | 90-110       |

Figure 20: GPS Sensors [45] [46] [47] [48]

The GPS Sensor was slightly different from the other sensors as there could only be one type and hence there was no comparison earlier. Furthermore, the accuracy of the GPS was really determined by the protocol and not by the sensor itself. The Gravity GNSS module [47] was selected as out of the four it seemed the most robust and reliable offering greater temperature ranges and UART comms capability, which was ideal for comms with the PIC.

### Connectors

The connectors used for this project were of the RS Pro SY-13 13mm IP67 connectors [49] and Molex [50] connectors. The SY-13 connectors would be used for casing connections to maintain waterproofness and onto sensors that were compatible with it. The SY-13 have rated currents of up to 5-13A and voltages of up to 125- 250V [51]. All of which is well within the parameters required for this project. The RS Pro SY-13 family also cover a wide

range of different pin numbers. Furthermore, the Molex connectors [50] wiring can easily be wired into the SY-13 [51].

For PCB connection and to sensors such as ambient light which were not compatible with the SY-13 so Molex connectors would be used. Figure 2 of the connector board on the casing shows the placement of 6 SY-13 male connectors for which a corresponding female SY-13 connector will connect to. This female connector would then be connected to the either directly to the sensor, like with the temperature and humidity sensor, or to a Molex connector which would plug into the sensor. To the PCB, the same is true except the Molex will be connected to the male SY-13 connector instead. Figure 21 below shows all the connectors required for each of the sensors.

| Component     | Sensor Connector     | Casing connector  | PCB connection |
|---------------|----------------------|-------------------|----------------|
| Temp & Humid  | 5 pin F              | 5 pin M SY-13     | 7 pin Molex F  |
| W Dir & Speed | 4 pin F              | 4 pin M SY-13     | 7 pin Molex F  |
| GPS           | 4 pin Molex F        | 4 pin M & F SY-13 | 4 pin Molex F  |
| Amb Light     | 5 pin Molex F        | 5 pin M & F SY-13 | 5 pin Molex F  |
| Airborne Part | 4 pin F              | 4 pin M SY-13     | 6 pin Molex F  |
| VOC           | 3 pin Molex F        | 3 pin F & M SY-13 | 5 pin Molex F  |
| UV            | 4 pin Molex F (1 NC) | 3 pin F & M SY-13 | 5 pin Molex F  |

Figure 21: Sensors used for each sensor [51] [50].

## PCB Design

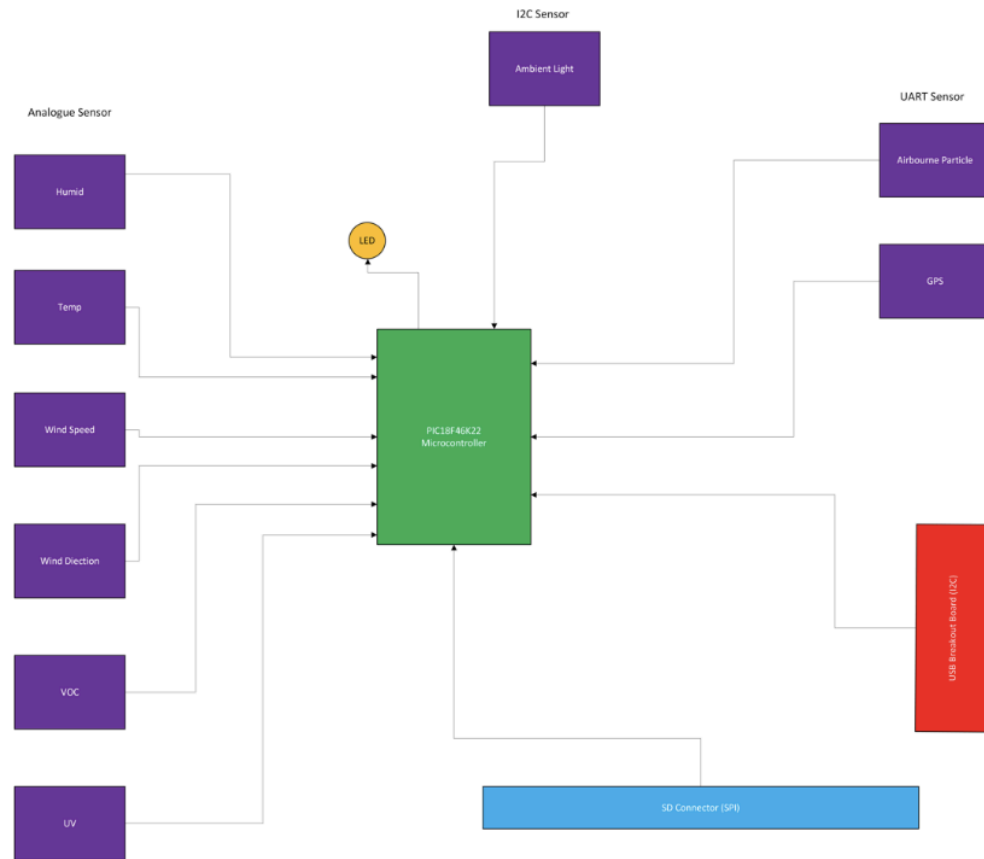


Figure 22: Block Diagram of PCB/ Hardware Components

This block diagram in figure 22 shows the basic hardware structure of the PCB showing the analogue inputs on the left and the I2C & UART sensors on the top right and then data transfer on the to either storage (SD) or to a computer via USB. Also, PCB has a LED tell to confirm the microcontroller is working.

The Easy-PC [2] schematics in figures 25 to 31 shows all the passive and active electronic components on the board. For all the analogue inputs a non-inverting amplifier is used to ensure the signal is at optimal input voltage followed by a 5.1V Zener diode to protect the microcontroller against surges in voltages. If a voltage greater than 5.1V is detected the Zener diode's breakdown voltage is reached and will be reversed biased and pull the excess voltage to ground maintaining a maximum of 5.1V on the input pin of the microcontroller. Furthermore, pull-up resistors are used on the I2C lines as the I2C protocols work by pulling the data line (SDA) low to start a communication with a peripheral device.

In figure 25 of the microcontroller in the Easy-PC [2] shows two 0.1uF decoupling capacitors by the VDD & VSS pins. This is done to reduce inductance and noise between the two pins

resulting better stabilisation of the power [7]. Attached to the Master Clear (MCLR) pin is a 10K ohm pull-up resistor to keep this pin high along with another 0.1uF decoupling capacitor and a manual push button. When the button pushed it resets the microcontroller to return it the start of its operation. It is useful for recovering from errors, debugging or to start a new program [7].

The LM317 [7] voltage regulator which converts the 5V power supply down to 3.3V for components such as the SD card and devices using I2C. The capacitors are arranged in such a way the output voltage is 3.3V. The formula for this assignment comes from the LM317 datasheet [11] and is shown in figure 31. Where  $V_{out}$  is 3.3v  $V_{ref}$  is the reference voltage (typically 1.25V [11]) and  $I_{adj}$  is the adjustment pin which is usually very small (50uA) and is negligible in most applications and so is ignored here. By selecting a resistance value of 240 oms for  $R_1$ ;  $R_2$  can be calculated as 394ohms so a 400ohm resistor could be used for  $R_2$ . The capacitors used are 0.1uF (Input) and 1uF (output) to help with transient response and noise rejection [11].

$$V_{OUT} = V_{REF} \left( 1 + \frac{R_2}{R_1} \right) + I_{ADJ}R_2$$

*Figure 23: LM317 voltage out ( $V_o$ ) formula [11]*

Other notable components are the connectors for the digital pins. The do not require any signal conditioning as the digital signals as they are less susceptible to inference and no voltage surges are expected. Finally, the last components on the PCB is the simple LED tell circuit which will flash for 1 second every 10 seconds to confirm the microcontroller to indicate its operation and the power connectors.

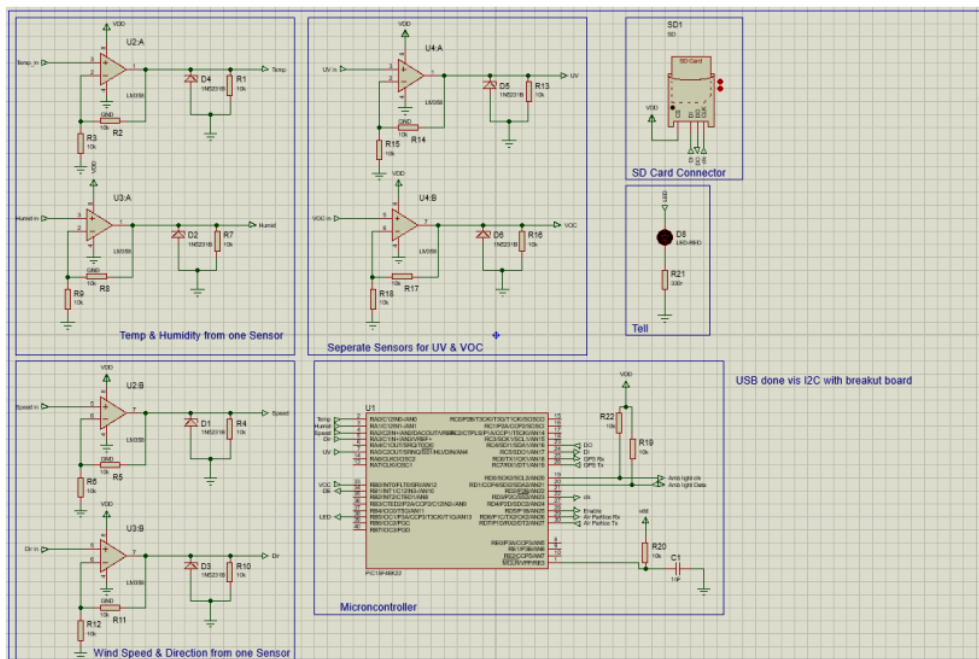


Figure 24: Proteus schematic design [1]

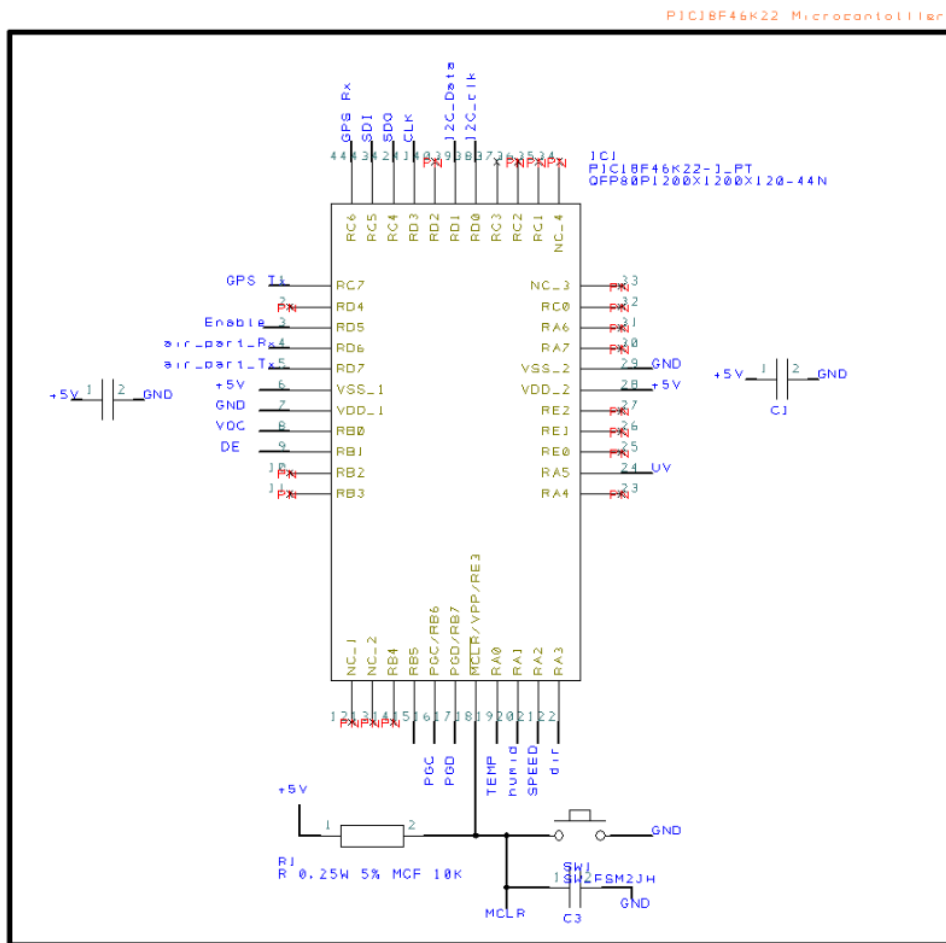


Figure 25: Easy PC set up the PIC18F46K22 microcontroller

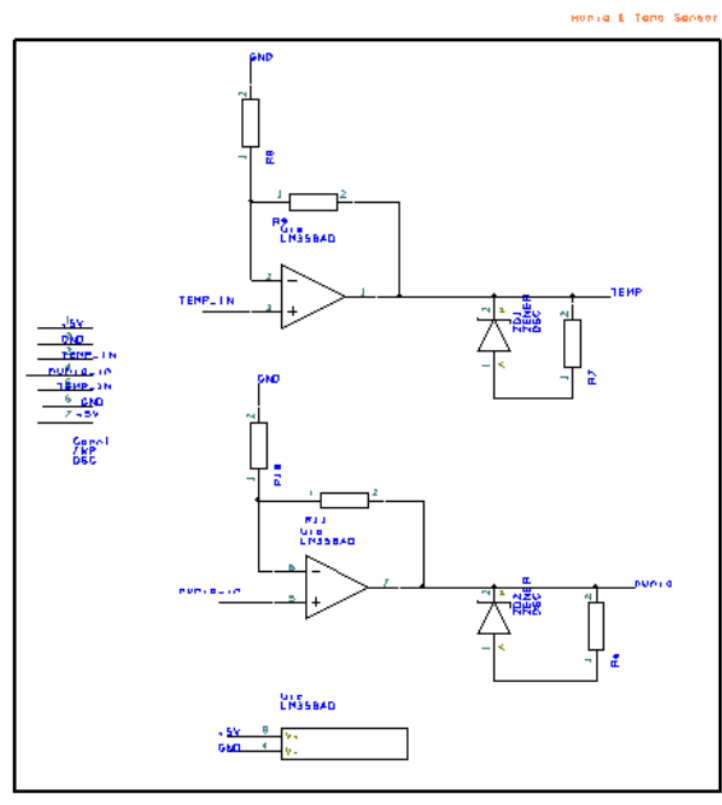


Figure 26: Inputs and signal conditioning for the temperature and humidity sensor.

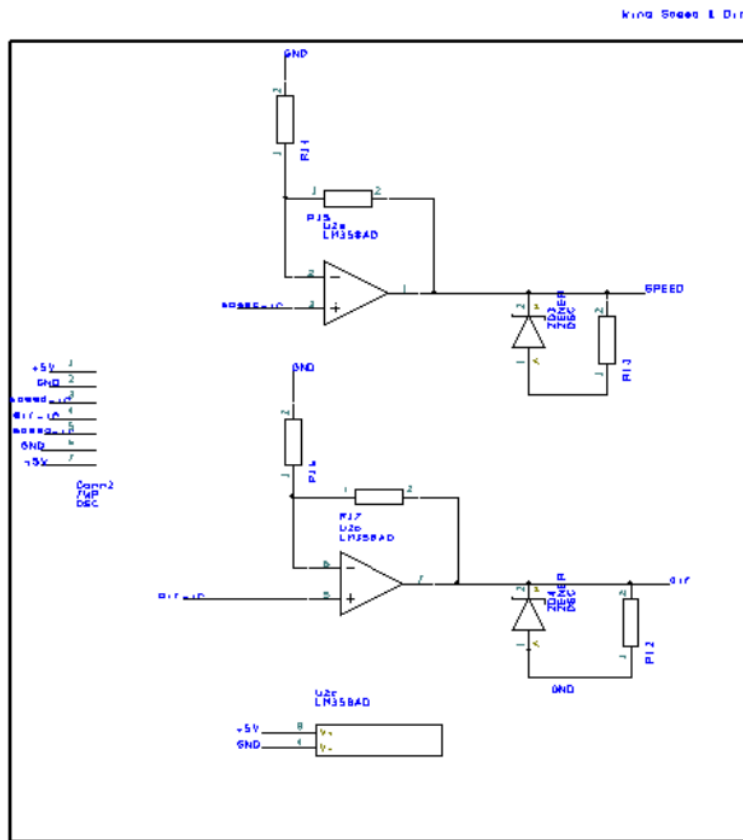


Figure 27: Wind speed & direction sensor signal inputs and signal conditioning

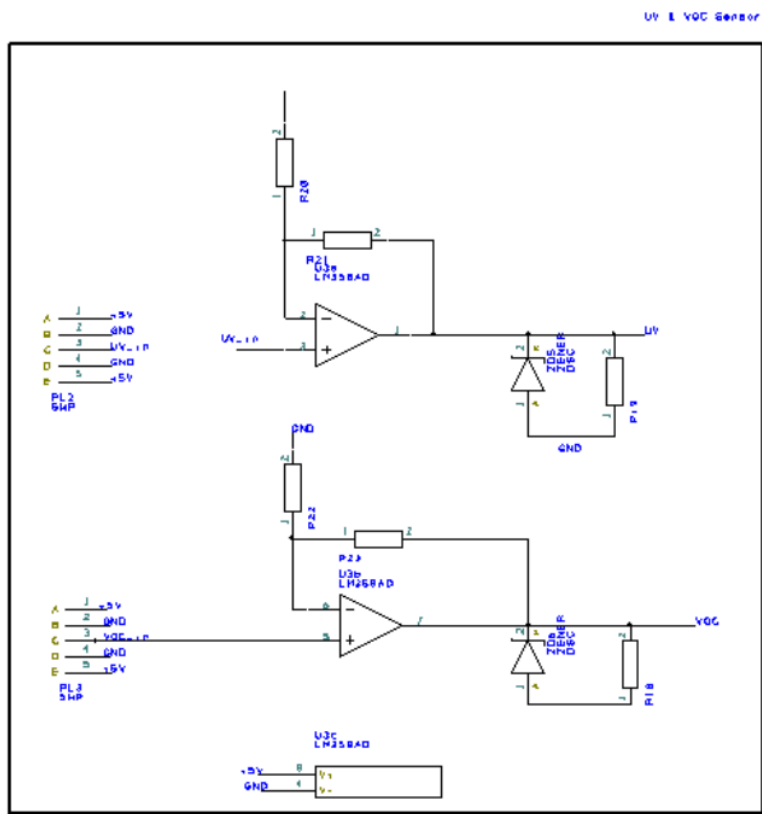
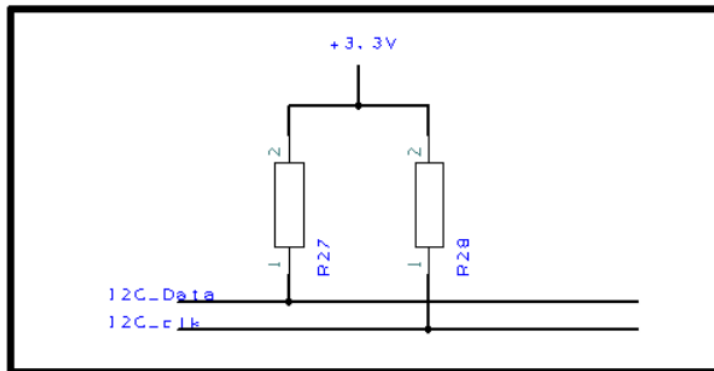


Figure 28: VOC & UV sensors inputs and signal conditioning

### I2C Pull-up Resistors



### Power Supply Pins & LED Circuit

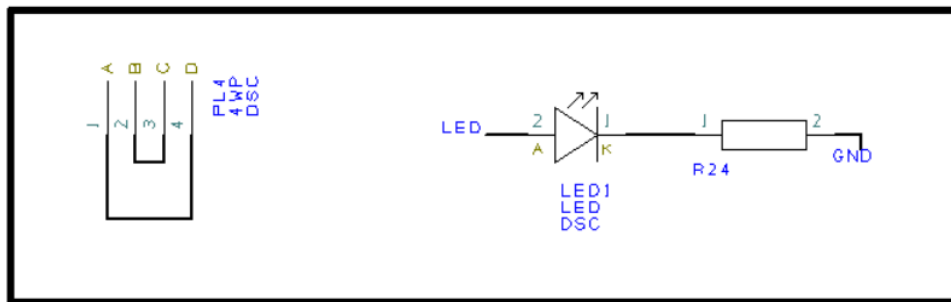


Figure 29: I2C pull-up resistors as well as power connectors and LED tell circuit

### Digital Data Ports

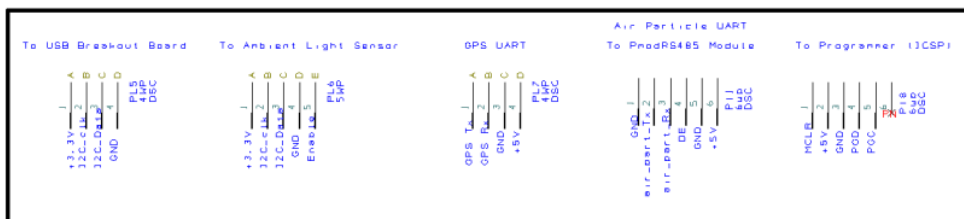


Figure 30: Digital signalling connectors

SD Connector & 5 to 3.3V Regulator Circuit

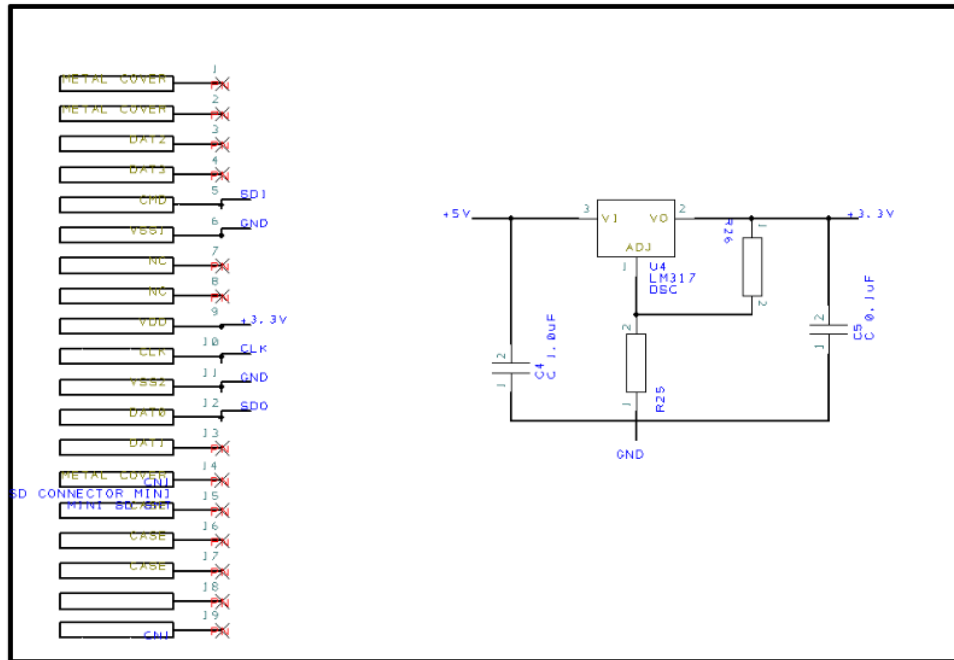


Figure 31: SD Card Connector & the Lm317 voltage regulator circuit to bring the voltage down from the supply (5V) to 3.3V required for some applications such as I2C and SD Connector.

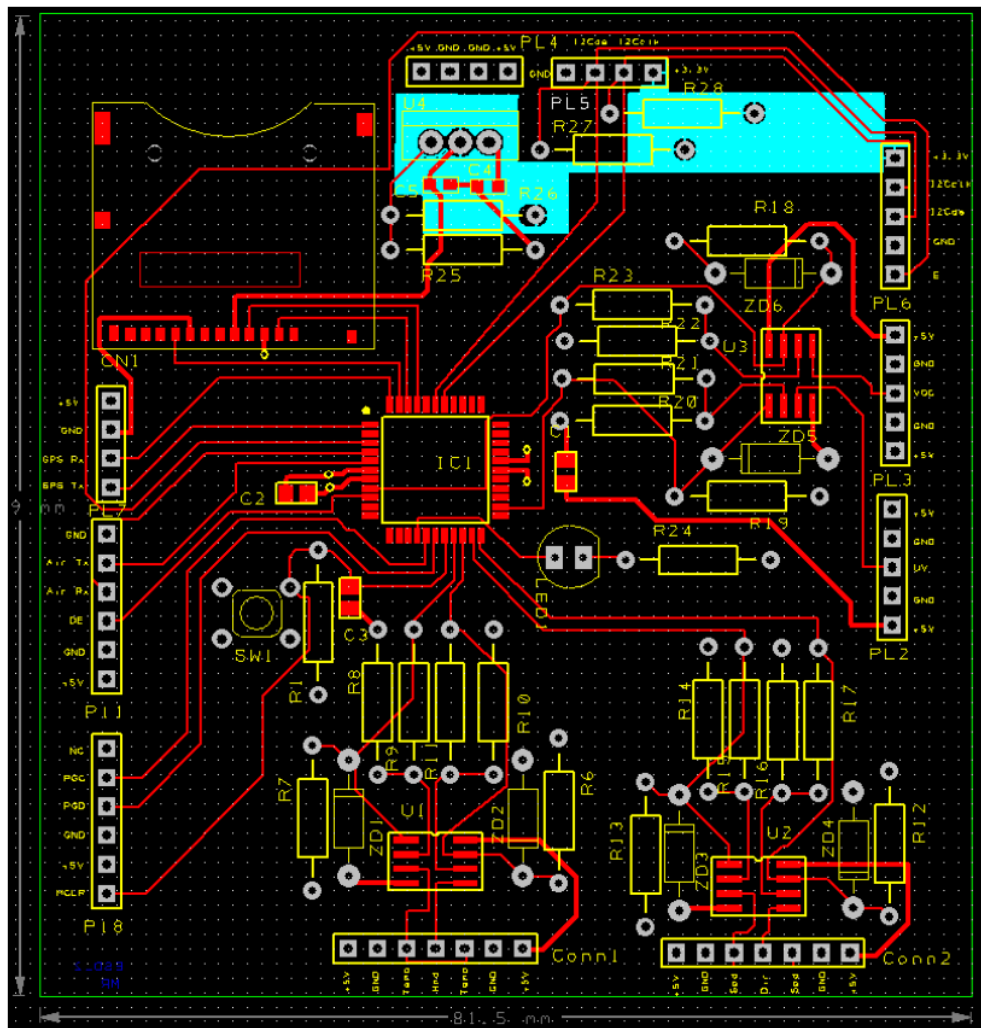


Figure 32: Easy PC PCB 2D design.

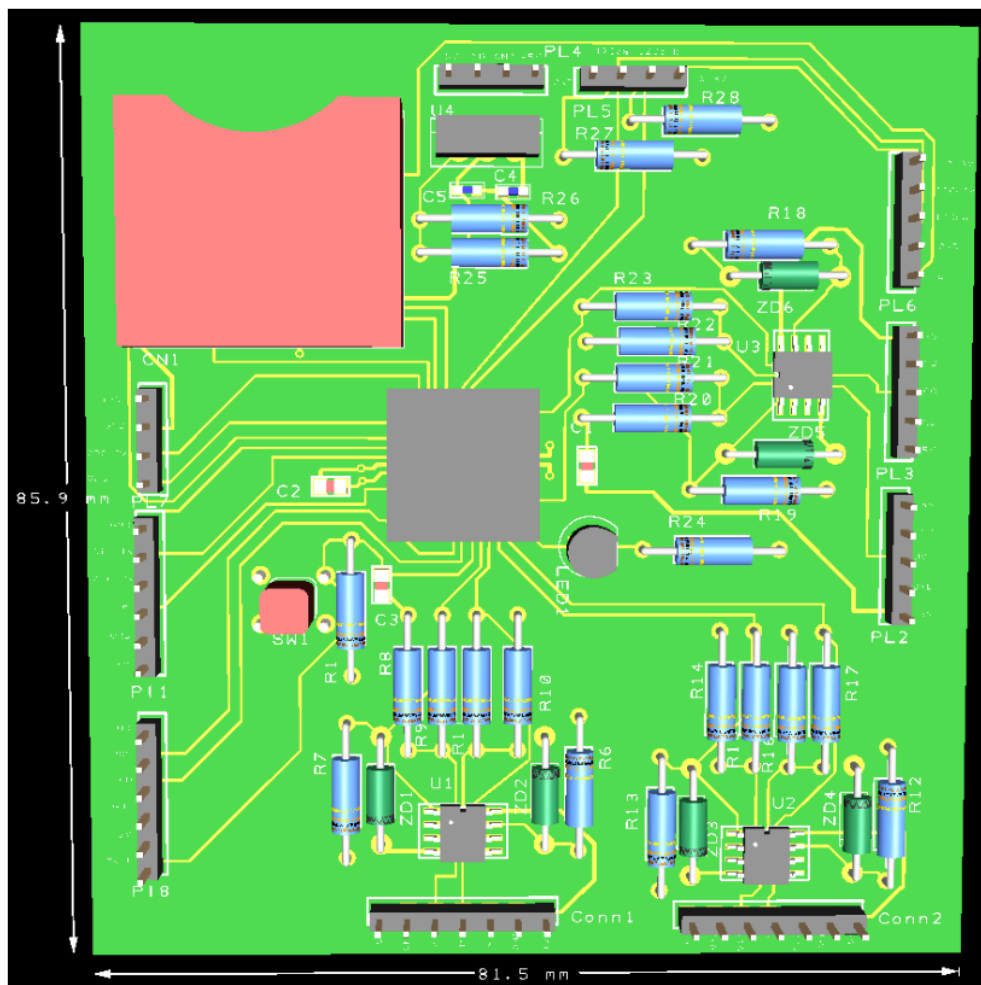


Figure 33: Easy PC 3D PCB view (Front).

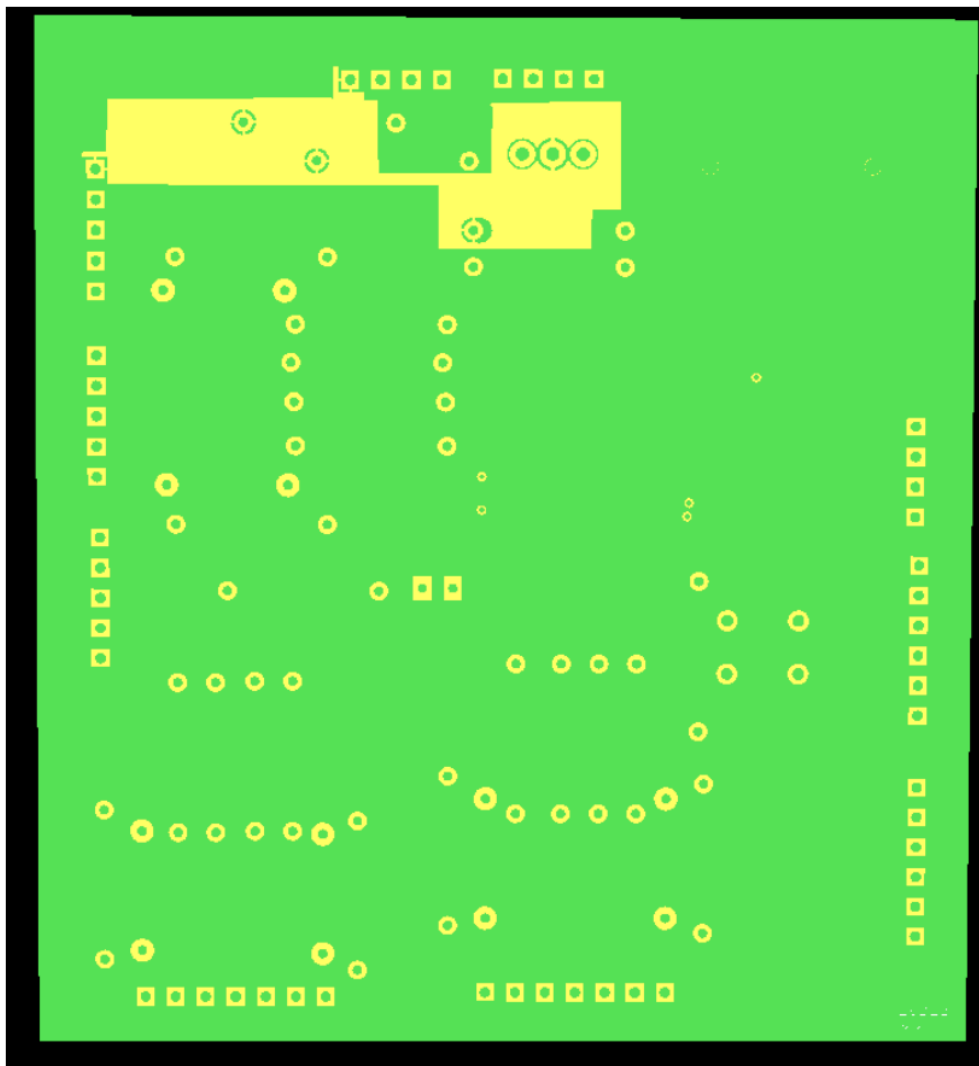


Figure 34: Easy PC 3D PCB view (Back).

## Prototype Software

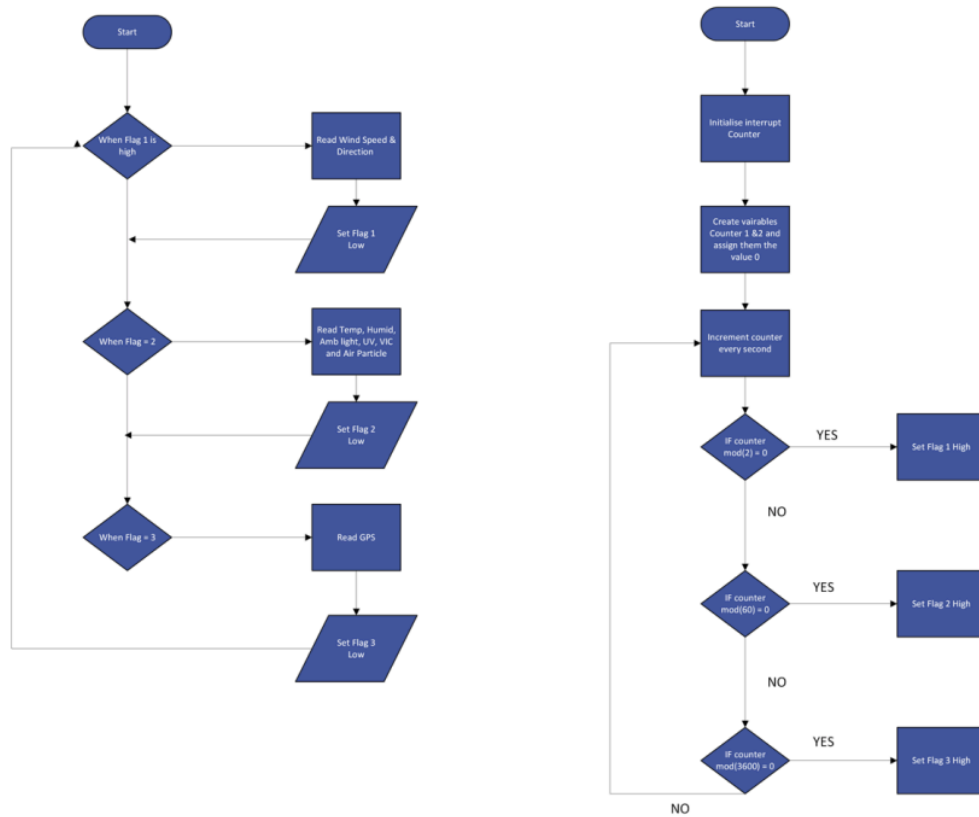


Figure 35: Flowcharts showing a basic software structure of the program that will be programmed onto the microcontroller.

## Build Costs

| Additional Parts            | Price (£)      | Reference |
|-----------------------------|----------------|-----------|
| PCB                         | 14.73          | [52]      |
| Voltage Regulator (LM317)   | 0.48           | [11]      |
| Battery 211Ah               | 599            | [53]      |
| USB I2C breakout (MCP2221A) | 6.3            | [8]       |
| Diligent pmodRS485 x2       | 69.92          | [9]       |
| Temperature/Humidity        | 119.08         | [27]      |
| Wind Speed & Direction      | 239            | [29]      |
| VOC                         | 109.75         | [36]      |
| UV                          | 3.12           | [43]      |
| Airborne Particle           | 81.89          | [33]      |
| Ambient Light               | 9              | [39]      |
| GPS                         | 18             | [47]      |
| GPS antenna                 | 4.62           | [47]      |
| Pelicanase 1200             | 83.72          | [13]      |
| 5 pin M x2                  | 16.68          | [49]      |
| 5 Pin F x3                  | 21.18          | [49]      |
| 4 pin M x3                  | 20.97          | [49]      |
| 4 pin F x3                  | 29.67          | [49]      |
| 3 pin F x2                  | 19.88          | [49]      |
| 3 pin male x2               | 13.6           | [49]      |
| Molex 7 F x2                | 7.54           | [54]      |
| Molex 6 F x3                | 16.38          | [55]      |
| Molex 5 F x2                | 13.34          | [56]      |
| Molex 4 F x1                | 4.4            | [57]      |
| Molex 3 F x1                | 2.32           | [58]      |
| Molex 4 pin f to f          | 3.79           | [59]      |
| LM358 op amp                | 2.04           | [60]      |
| PIC18F44K22                 | 3.73           | [7]       |
| Resistors                   | 0.84           | [61]      |
| Capacitors                  | 1.9            | [62]      |
| LED                         | 0.06           | [63]      |
| SD Card Conn                | 2.7            | [64]      |
| 7 pin PCB conn x2           | 0.14           | [65]      |
| 6 pin PCB conn x3           | 0.75           | [66]      |
| 5 pin PCB conn x3           | 0.39           | [67]      |
| 4 pin PCB conn x3           | 0.39           | [68]      |
| 6 to 6 pin PCB conn x2      | 1.38           | [69]      |
| SD Card                     | 8.90           | [51]      |
| button                      | 0.28           | [70]      |
| <b>Total</b>                | <b>1542.96</b> |           |

Figure 36: Table of build cost for the project.

## Improvements

A number of improvements for any next iterations to the project have been considered from the research in the Literature review but also from working on the project and identifying areas where the design could be enhanced:

- Power Supply: It was calculated that a minimum 100Ah battery was required to power this project. This seems very high considering the majority of the sensors are only taking a reading every minute and only draw mA as a maximum. A method to improve this is to have Solar assisted power supply like with the ACCUR8 DWS7100 [3] in the literature review. This way the battery size can be smaller and therefore make the whole system more portable and efficient.
- Optimisation of Sleep Modes: Because the interval of all the sensors is relatively slow to what the PIC18F46K22 [7] is capable of sleep modes programmed into the software could be used to reduce the overall power consumption of the system and making it more efficient.
- Use of Wireless Communication: For many of the weather stations identified in the literature review such as the ACCUR8 DWS7100 [3] use Wi-Fi to communicate with a remote interfacing module. However, potentially using wireless comms to sensors could be a way to read some sensors could be beneficial as the portable casing could be placed in areas slightly less local which offer more protection from the elements.
- Interfacing Unit: All the weather station in the literature review have interfacing units which enable the user to get real-time measurements.
- Barometric Pressure & Precipitation: Sensors like the National Geographic 9080500 [5] offer barometric pressure & precipitation sensors which is could be useful to measure on future projects as it will offer greater understanding of the weather situation.
- Calculation of Phenonium based of Sensors: The weather stations including the Davis Wireless Vantage Pro 2 [6] offer further understanding of the environment by calculating phenonium such as Dew Point [71] based of the humidity and temperature sensors. Including functionality like this in future projects to gather a greater understanding of the outdoor environment.

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FINAL GRADE

GENERAL COMMENTS

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MATT RUSSELL

71.55

## RESEARCH-INFORMED LITERATURE



Limited literature review of a number of available systems with a good comparison table of relevant information but more detail would have improved it. 62%

6.2

## KNOWLEDGE AND UNDERSTANDING



Good overall schematic design but a things to be kept in mind. When designing a complex board it is beneficial, from a understanding point of view, to limit the number of lines travelling around and instead use net names which you have done. There are a number of errors on the PCB which should have been caught and corrected. Your clamps will do nothing as the resistor is in the wrong place, it should be the at the start and be between 10-50 ohms and there should also be a small cap across the output. 65%

16.25

## ANALYSIS



Good selection of microcontroller. Good selection of components very well described and selected

27.3

via the tables.. Good case selection. Good selection of connectors .78%

#### **PRACTICAL APPLICATION AND DEP.**

 Costings were included in a table without an image but with a link to the supplier's name and part number, this would have been better placed in the text.. Good attempt at future enhancements. 73%

**14.6**

#### **SKILLS FOR PROFESSIONAL PRAC.**

 The report is well presented with a good selection of references. 72%

**7.2**