

SL_ESD2

by Sam Lloyd

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Introduction

The following brief was given for the task:

"You are required to design a simple microcontroller-based weather and air quality monitor / logger which takes measurements and logs the data over a 14 day period

The data acquisition system is intended for use by amateur weather forecasters to aid in their predictions. The system must be portable and adaptable for a number of monitoring sites.

The following data will be acquired during the 14-day cycle:-

- *Temperature*
- *Humidity*
- *Wind Speed*
- *Wind Direction*
- *Air borne particle count*

- Sunlight brightness
- UV levels
- GPS position
- VOC level

The system must:

Store the collected data to non-volatile memory which may be externally read and cleared when connected to a computer via USB.

Have its own battery so that it may continue monitoring even when the site is remote and unpowered.

Ensure that your design is portable, adaptable, and suitable for operation in its intended environment.

This design does not require a display except for a LED which flashes once every 10 seconds for 1 second to indicate operation.” [1]

From this information, the aim of this task is to research and design a weather station to collect a range of information that can be used to attempt to create forecasts for future weather in the surrounding [2]. In the case of a singular system this is not possible so this system will be used more for tracking weather that has occurred in the past 2 weeks. With the brief given the following things will be looked at and researched and considered for the final product:

- PIC micro controller:
This will have considerations for memory size, pin out, analogue and digital and more.
- Sensors:
In this section this will consider what types of sensors are the most appropriate for the job, then once the type is decided looking into sensors of this type and finding one with the appropriate accuracy, data output rate, data output type, costing and more
- Circuit design:
In this part of the planning a circuit diagram and PCB will be designed and ready in a state to print. The circuit will include any required power regulators, clamps, signal conditioning and anything else required.
- Enclosure:
1 or more enclosures sized appropriately to include the PCB, connectors and the PSU and sensors that need to be enclosed.
- Software structure
This section will show how the systems programming will operate, giving a guide for how the program will be structured and the requirements needed.
- Power supply
For the Supply voltage this will be 12V, using values from data sheets of sensors and other components a watt's calculation will be made to select and appropriate sensor for the job.

Research

Literature review

Bellow will show examples of existing products showing the positives and negatives of these systems, this knowledge will be used throughout in considerations for the product and possible future improvements that can be made:

1. Ecowitt Weather Stations WS2910 [3] seen in Figure 1

Positives

Large collection of sensors on one system, additionally including a rain gauge.
Good live display for users showing max/min for the days weather.
Can be operated from 100m range.
Easy install, using bubble level to aid
Solar powered.
1-degree Celsius accuracy on temperature.

Negatives

Reporting period of 16 seconds may mean large gusts are missed.
Unclear how long data is stored beyond a day.
Unclear on data precision apart from temperature.
No sensors for VOC, Airborne particle counter and UV level.

Table 1: Ecowitt Weather Stations WS2910 positives and negatives



Figure 1: Ecowitt Weather Stations WS2910 [3]

2. ACCUR8 DWS5100 5-in-1 Solar-Powered Wi-Fi Weather Station [4] seen in Figure 2

Positives

Can collect information and share it using the Wi-Fi connectivity.
Additionally has an app so can view live data on this.
Easy pole attachment which can be connected to a post.
Programable alarms for extreme weather.
Large range of Temperatures, humidity, wind direction and rainfall.
Data storage for week.
Additional "feels like" temperature combining head and wind chill.

Negatives

Hourly recording meaning misses wind gusts and more regular changes.
Minimal sensors do not include a lot of sensors you may want to include.
Though a range is given it is unclear at the level of precision

Table 2: ACCUR8 DWS5100 5-in-1 Solar-Powered Wi-Fi Weather Station positives and negatives



Figure 2: ACCUR8 DWS5100 5-in-1 Solar-Powered WiFi Weather Station [4]

3. Digitron AM60 Data Logging Air Quality Monitor [5] seen in Figure 3

Although this is not a weather station this has been included to show what an indoor sensor looks like and what this includes

Positives	Negatives
Good and clear display for tracked data. Compact system. Stores data for a week and can display this data as well. Can set an alarm if any values go above the expected values. High level of precision as seen on data sheet	Built for indoor use. Due to this does not have the ability to record a lot of parts required in a weather station.

Table 3: Digitron AM60 Data Logging Air Quality Monitor positives and negatives



Figure 3: Digitron AM60 Data Logging Air Quality Monitor [5]

None of these devises have all the requirements desired but all show different techniques on how to do these things.

Component research

PIC requirements

When selecting an appropriate PIC for the project there are many important requirements to consider. Some of these are the Pins that are required, how many analogue and digital, what processing speed is needed in the task, memory size, any other types of connections for example I2C and UART. For the PIN requirements this will be decided after the sensors are selected.

For the memory calculations decision needed to be made on bytes per reading and readings per second, the following can be seen in Table 4. Additionally, within this table are the calculations to find the total data produced in a 2-week period. This comes out as 1.7MB. This doesn't include the GPS data; this will only require 32 bytes as will only be recorded at the start of the readings.

Sensor	Bytes per Read	Time per Read	Record (bytes per hour)
Temperature	1	600	6
Humidity	1	600	6
Wind speed	1	2	1800
Wind direction	1	2	1800
Air borne particle count	2	3600	2
Sunlight brightness	2	10	720
UV levels	2	10	720
VOC levels	2	3600	2
		record total	5056
		2 week total	1698816

Table 4: Memory calculations

In this case there are no requirements for a high processing speed as all the readings are done at a slow rate, due to this any PIC selected will have a processing speed high enough for the requirements. The operating voltage will be 3.3 or 5 volts unless there is a requirement for more. The pin requirements will be decided after the sensors are selected. The Final pic will be selected later.

Sensor requirements

In this section there will be a discussion on what sensor types are available and what choices will be used in this product weighing up the pros and cons of each and giving a brief conclusion on why.

Temperature options

Sensor Type	Positives	Negatives
Thermistor [6] Seen in Figure 4: Thermistor Figure 4	Accurate and Rapid response	Small Temperature range

Thermocouple [6] Seen in Figure 5	Massive temperature range	Less accurate than a thermistor
Semi-Conductor [7] Seen in Figure 6	small size, high accuracy, stability	Expensive, hard to get
Wet Bulb [8] Seen in Figure 7	Very Accurate	Complex setup, would require digitalization

Table 5: Temperature options

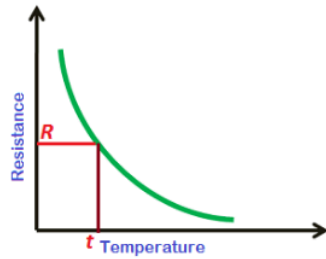


Figure 4: Thermistor [7]

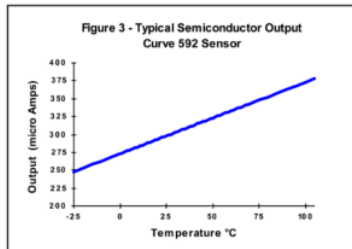


Figure 6: Semiconductor output [11]

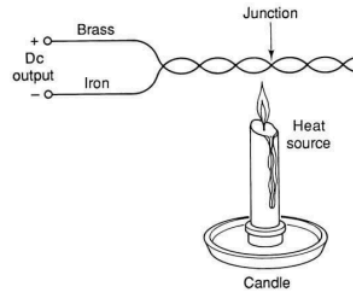


Figure 5: Thermocouple [10]

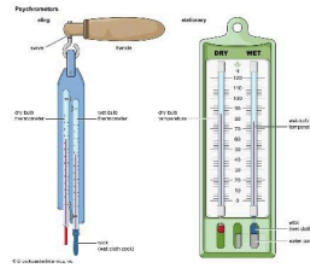


Figure 7: Wet Bulb setup [12]

Temperature conclusion

In this case due the accurate and rapid response a thermistor will be used.

Humidity

Sensor Type	Positives	Negatives
Capacitive [13] Seen in Figure 8	Low cost, can detect 0% to 100%, stable results	Requires short distance communication
Resistive [13] Seen in Figure 9	Can be used in long distance	Sensitive to contamination
Thermal conductivity [13] Seen in Figure 10	Very resistant, stable in high temperature and corrosive environments	Exposure to gasses other than nitrogen can affect results
Wet Bulb [8] Seen in Figure 7	Very accurate	Complex setup, would require digitalization

Table 6: Humidity options

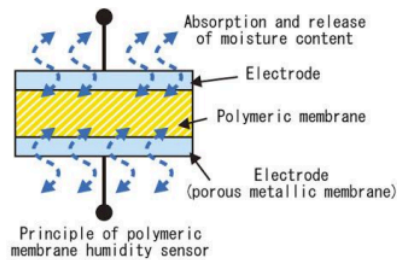


Figure 8: Capacitive sensor [14]

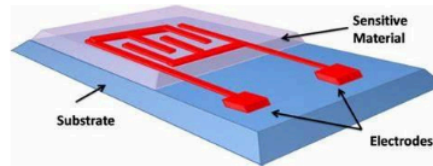


Figure 9: Resistive [15]

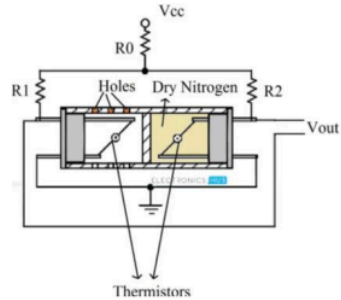


Figure 10: Thermal conductivity sensor [16]

Humidity conclusion

For the Humidity sensor a resistive Sensor will be used.

Wind Speed

Sensor Type	Positives	Negatives
Rotating Cup [17] Seen in Figure 11	Simple to use, cheap	Strong winds can create distorted results
Wind Pressure [17] Seen in Figure 12	Very accurate	Requires a minimum speed to read anything
Ultrasonic [17] Seen in Figure 13	Can measure speed and directions accurately	Very expensive
Thermal [17] Seen in Figure 14	Low cost, accurate at low and medium speeds	No products sold that are not part of a system

Table 7: Wind Speed options

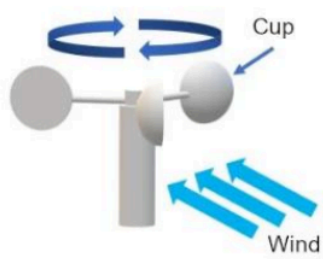


Figure 11: Rotating cup [17]



Figure 12: Pressure [17]

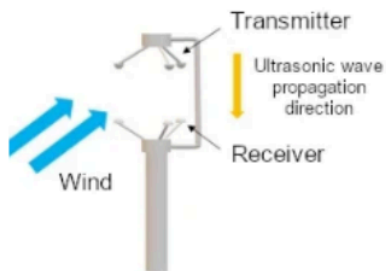


Figure 13: Ultrasonic [17]

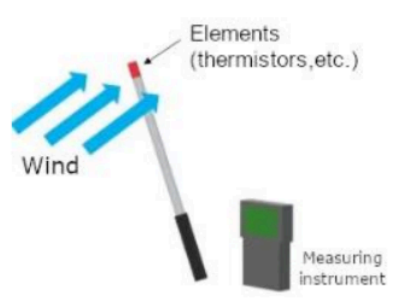


Figure 14: Hot wire [17]

Wind speed conclusion

In this case for a household product the best option is to use a rotating cup due to the low cost a simplicity to setup and use.

Wind Direction options

Sensor Type	Positives	Negatives
Digital wind vane [18] Seen in Figure 15	Cheap, simple, easy to use	Required to be setup facing a set direction
Windsock [18] Seen in Figure 16	Cheap	Would require digitalization, inaccurate results

Table 8: Wind Direction options



Figure 15: Weathervane [18]



Figure 16: Windsock [18]

Wind Direction conclusion

In this case the best option is to use a wind vane sensor due to the accuracy and the fact it would not require digitalization. Another possibility is the Ultrasonic sensor discussed in "Wind speed", this would have been considered if it was the pick within the wind speed section.

Air Bourne Particle Count options

Sensor Type	Positives	Negatives
Passive	Creates a very accurate result	This is not a possible option as would not create a live result
Optical Counter [19]	Would provide a live and digital result	Not waterproof and bulky

Table 9: Air Bourne Particle Count options

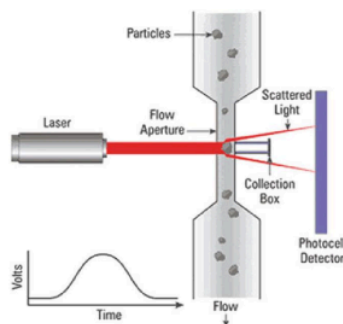


Figure 17: Example optical counter [20]

Air Bourne Particle Count conclusion

In this case the only real method is using an optical particle counter as the passive method would require taking a sample and putting it into a machine meaning it is not possible to be active in this use case.

Sunlight brightness options

Sensor Type	Positives	Negatives
Light dependent resistor (LDR) [21] Seen in Figure 18	cheap, small, high sensitivity	slow response, less accurate
Photo Diode [22] Seen in Figure 19	durable, fast response, high sensitivity, wide range of wavelengths	Susceptible to noise interference
Phototransistor [23] Seen in Figure 20	sensitive to a wide range of wavelengths, high reliability	effected by EM energy, bad with low levels of light

Table 10: Sunlight brightness options

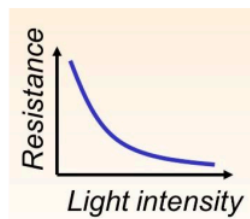


Figure 18: LDR graph [24]

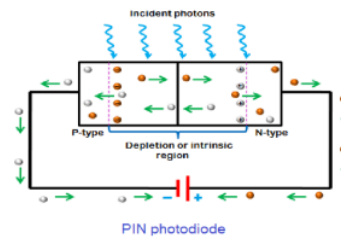


Figure 19: photo diode [25]

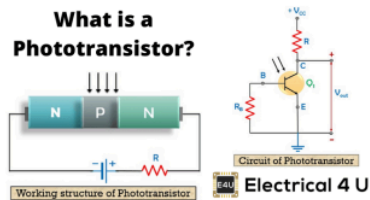


Figure 20: Phototransistor [26]

Sunlight brightness conclusion

In this case a Photo Diode will be used due to the ease of access and precision.

UV Levels options

Sensor Type	Positives	Negatives
Radiometer [27] Seen in Figure 21	Accurate readings	Not possible to buy as a small sensor
Photo diode [28] Seen in Figure 22	Cheap, readily available as a small sensor, rapid results, sensitive.	Very low current change, will require amplification
Dosimeter [29] Seen in Figure 23	Different sensors depending on the UV types desired	Handheld device, can be bought as a raw sensor

Table 11: Sunlight brightness options



Figure 21: Radiometer [27]

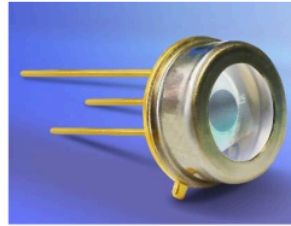


Figure 22: Photo diode [28]



Figure 23: Dosimeter [29]

UV Levels conclusion

For this a Photo Diode will be used as it's the most sensible for this setup for the reasons shown above.

VOC Level options

Sensor Type	Positives	Negatives
Metal Oxide Semiconductor (MOS) Sensors [30] Stage 1 seen in Figure 24 Stage 2 seen in Figure 25	Low cost, detect a wide range of VOC's	Sensitive to changes in humidity and temperature
Photoionization Detectors (PIDs) [30] Seen in Figure 26	Rapid detection, capable of detecting at low levels	Don't work with VOC's with a high energy level, expensive
Infrared [30]	Can be used to find specific VOC's depending on the IR value, high accuracy, no sensor drift	No as sensitive at low concentrations, more expensive

Table 12: Sunlight brightness options

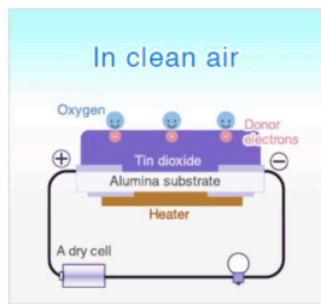


Figure 24: MOS in clean air [30]

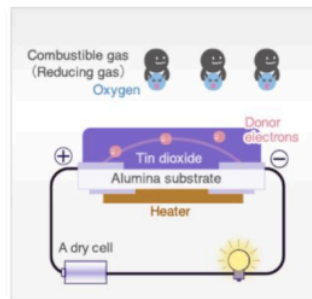


Figure 25: MOS in dirty air [30]

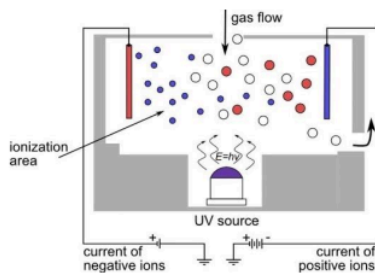


Figure 26: PID sensor [30]

VOC Level conclusion

The chosen sensor type for this will be the MOS sensor due to the low cost and wide detection of all types of VOC.

GPS

For GPS sensors there are no varying types this is only GPS sensors.

Final Design

Chosen components

Chosen sensors

Temperature and humidity sensor

Options

Sensor	Positives	Negatives
TE Connectivity Temperature & Humidity Sensor [31] Seen in Figure 27	analogue sensor, 5V supply, +-2% RH @55%RH, range from -40 to 85, +- 1% temp, through hole	expensive, requires 2 data pins
STEGO IO-LINK Temperature and Humidity Sensor [32] Seen in Figure 28	analogue out, -40 to 80 +- 0.2 temp, +-2 RH, Cheap, through hole	Only IP 20 rating
Honeywell HIH7000 Series Temperature & Humidity Sensor [33]	through hole	I2C output, no IP rating

Seen in Figure 29		
DFRobot Gravity: DHT11 Temperature & Humidity Sensor For Arduino [34] Seen in Figure 30	5V supply	0 to 50 range, digital output, 20 to 90% RH +-5%, no IP rating

Table 13: Temperature and Humidity sensors



Figure 27: TE Connectivity Temperature & Humidity Sensor [31]



Figure 28: STEGO IO-LINK Temperature and Humidity Sensor [32]

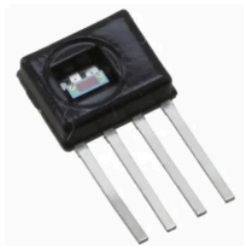


Figure 29: Honeywell HIH7000 Series Temperature & Humidity Sensor [33]

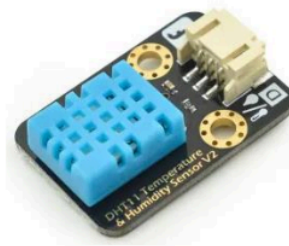


Figure 30: DFRobot Gravity: DHT11 Temperature & Humidity Sensor for Arduino [34]

Final selection

Due to the accuracy and simplicity of the sensor, the chosen device will be the TE Connectivity Temperature & Humidity Sensor. This will give a simple to read analogue output which can be monitored and if it is later concluded that a larger polling of the data is needed this will be simple and easy to change.

Wind Speed & Wind Direction

Options

Sensor	Positives	Negatives
Carlo Gavazzi DWS Series Cup Anemometer - DWS-V-DBC05 [35] Seen in Figure 31	3 to 30m/s $\pm$ 10%, IP 54	expensive, requires a 12-14v supply
Carlo Gavazzi DWS Series Cup Anemometer - DWS-V-AGP [36] Seen in Figure 32	winds 2-50 m/s, $\pm$ 10%, IP 54, not effected by cold weather due to built in heater	expensive, 18-24V supply required

Anemometer Wind Speed Sensor w/Analog Voltage Output [37] Seen in Figure 33	analogue output, works with up to 32m.s wind speed, high resolution, cheap	9V supply, 0.3 to 2v output
MeteoWind® Compact [38] Seen in Figure 34	combines cup and vane sensors, 0-85 m/s, +- 0.02 m/s, 0-360° direction, +-2° accuracy, digital data for speed and analogue for direction, 3.2 to 15V supply	Large, expensive (could not get full price), 0 to 2.5V output for direction
RS485 Wind Direction Transmitter [39] Seen in Figure 35	comes with cable, low startup speed	RS485 output
Wind Speed & Direction Integrated Sensor Wind Vane Transmitter Weather Detector [40] Seen in Figure 36	IP 65, 0-5V, low cost	0-30 m/s speed +-3%, direction 0-360° broken down into 16 directions (+- 22.5°)
BlueSiren Wind Speed Sensor [41] Seen in Figure 37	Wind speed 0 to 78m/s, +-5%, 12m cable	Wind direction 0-355° or 16 directions output, unclear documentation on output types
NRG 200M Wind Vane [42] Seen in Figure 38	High level of accuracy, analogue output	expensive (could not get full price)

Table 14: Wind Speed and Direction Sensors



Figure 31: Carlo Gavazzi DWS Series Cup Anemometer - DWS-V-DBC05 [35]



Figure 32: Carlo Gavazzi DWS Series Cup Anemometer - DWS-V-AGP [36]



Figure 33: Anemometer Wind Speed Sensor w/Analog Voltage Output [37]



Figure 34: MeteoWind® Compact [38]



Figure 35: RS485 Wind Direction Transmitter [39]



Figure 36: Wind Speed & Direction Integrated Sensor Wind Vane Transmitter Weather Detector [40]



Figure 37: BlueSiren Wind Speed Sensor [41]



Figure 38: NRG 200M Wind Vane [42]

Final selection

As seen above all sensors that are combined come with a higher cost, the final decision is to use the individual sensors found, using the "Anemometer Wind Speed Sensor w/Analog Voltage Output" and the "RS485 Wind Direction Transmitter".

Air Bourne Particle Count

Options

Sensor	Positives	Negatives
TERA Sensor Next-PM, Particle Matter / Dust Air Quality Sensor [43] Seen in Figure 39	Options for a 1/15/60s refresh rate, 5V supply, good accuracy and readings, counts and then transmits data, UART output	Expensive, can-do temperature and humidity but exposed circuitry wouldn't be able to be exposed and operate in an outdoor environment
PMS5003 Particulate Matter Sensor with Cable [44] Seen in Figure 40	good working temperature range, accurate results output, UART output, 5V supply. cheap	Requires an enclosure as no IP rating
Sensirion SPS30 Sensor & USB adapter cable Particulate Matter Sensor Evaluation Kit for SPS30 [45] Seen in Figure 41	High level of accuracy, good working temperature rating UART output, 5V supply	Comes with USB cable connection, expensive

Table 15: Air Bourne Particle Count Sensors



Figure 39: TERA Sensor Next-PM, Particle Matter / Dust Air Quality Sensor [43]



Figure 40: PMS5003 Particulate Matter Sensor with Cable [44]



Figure 41: Sensirion SPS30 Sensor & USB adapter cable Particulate Matter Sensor Evaluation Kit for SPS30 [45]

Final selection

Due to the reasons above the selected sensor will be the PMS5003 Particulate Matter Sensor with Cable

Sunlight Level

Options

Sensor	Positives	Negatives
Ambient Light Sensor(0-200klx) [46] Seen in Figure 42	Easy to set up, high level of variation, large range of light inputs, large operating	I2C required

	temperature range, 2.7-6V supply	
Grove - Sunlight Sensor [47] Seen in Figure 43	3.3-5V Supply, large operating temperature range	I2C communication, unable to find accuracy or light range data, would require casing
Hamamatsu, S1223-01 Full Spectrum Si Photodiode, Through Hole TO-5 [48] Seen in	Analogue output	Unclear data sheet, would require casing
Hamamatsu, S5971 IR + Visible Light Si Photodiode, Through Hole TO-18 [49] Seen in Figure 45	Analogue output	Unclear data sheet, would require casing

Table 16: Sunlight Level Sensors



Figure 42: Ambient Light Sensor(0-200klx) [46]



Figure 43: Grove - Sunlight Sensor [47]



Figure 44: Hamamatsu, S1223-01 Full Spectrum Si Photodiode, Through Hole TO-5 [41]



Figure 45: Hamamatsu, S5971 IR + Visible Light Si Photodiode, Through Hole TO-18 [42]

Final selection

Due to the ease of use and the clear data sheet the sensor to use for sunlight will be the Ambient Light Sensor(0-200klx).

UV Level

Options

Sensor	Positives	Negatives
Analog UV Light Sensor Breakout - GUVB-S12SD [50]	Analogue, 5V supply, small, cheap, suitable operating range	Requires an enclosure, 0-4.3V out
OSI Optoelectronics, UV-035EQ UV Si Photodiode, Through Hole TO-8 [51]	Analogue, through hole setup, 5v supply	Unclear on accuracy

AS7331-AQFM ams OSRAM, UV Light Sensor, I2C 16-Pin OLGA16 [52]	5v supply, sensible operating temperature, suitable value range and accuracy	Requires I2C, complex pin out setup requiring external resistance.
SparkFun Mini Spectral UV Sensor - AS7331 (Qwiic) [53]	3.3v supply, suitable output range	I2C output

Table 17: UV Level Sensors

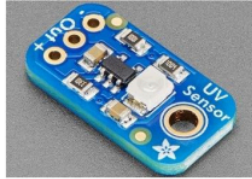


Figure 46: Analog UV Light Sensor Breakout - GUVVA-S12SD [50]



Figure 47: OSI Optoelectronics, UV-035EQ UV Si Photodiode, Through Hole TO-8 [42]

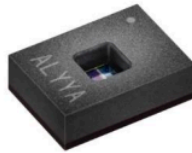


Figure 48: AS7331-AQFM ams OSRAM, UV Light Sensor, I2C 16-Pin OLGA16 [52]



Figure 49: SparkFun Mini Spectral UV Sensor - AS7331 (Qwiic) [44]

Final selection

For this the chosen sensor is the "Analog UV Light Sensor Breakout - GUVVA-S12SD" for the advantage of having an analogue output and a simple to connect circuit.

VOC Levels

Options

Sensor	Positives	Negatives
Grove - VOC and eCO2 Gas Sensor (SGP30) [54]	Cheap	Complex to leave the sensor exposed due to sensor location
SGX Sensors PS1-VOC-10-MOD, Organic Vapour Gas Sensor IC for VOC Monitors [55]	Could setup the sensor the be exposed by creating a hole in the storage unit, appropriate accuracy	Expensive
Sensirion SGP40-D-R4, VOC Air Quality Sensor for VOC Monitors [56]	Cheap, simple setup	I2C output
SGX Sensors PS1-VOC-1000, Organic Vapour Gas Sensor IC for VOC Monitors [57]	Means could receive raw data and could be connected directly to the main PCB	Would require a mounting method, would require calibration, would require monitoring the current draw.

Table 18: VOC Level Sensors

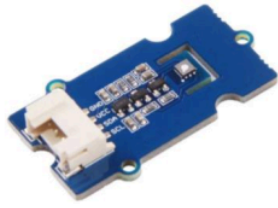


Figure 50: Grove - VOC and eCO2 Gas Sensor (SGP30) [54]



Figure 51: SGX Sensors PS1-VOC-10-MOD, Organic Vapour Gas Sensor IC for VOC Monitors [55]

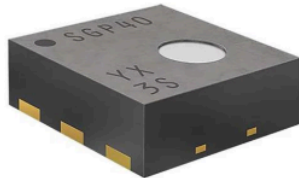


Figure 52: Sensirion SGP40-D-R4, VOC Air Quality Sensor for VOC Monitors [49]

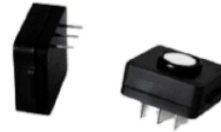


Figure 53: SGX Sensors PS1-VOC-1000, Organic Vapour Gas Sensor IC for VOC Monitors [57]

Final selection

In this case using the “Sensirion SGP40-D-R4, VOC Air Quality Sensor for VOC Monitors” is simpler due to other use of UART and attempting to reduce the PIN requirements a use of I2C is simpler for circuit design.

GPS

Options

Sensor	Positives	Negatives
PA1010D GPS Breakout [58]	3.3 or 5V supply, single board operation, high level of accuracy	I2C output, requires enclosure
Garmin 16x GPS Sensor [59]	High accuracy, rapid response, 5V supply, waterproof	Output via ethernet, expensive
Seeed Studio 113020003 GPS Module [60]	Large working temp range, I2C output, 3.3 supply	2-part board, requires enclosure
Grove - GPS (Air530) [61]	Cheap, high level of accuracy, UART output	2-part board, requires enclosure

Table 19: GPS Sensors



Figure 54: PA1010D GPS Breakout [58]



Figure 55: Garmin 16x GPS Sensor [59]



Figure 56: Seeed Studio 113020003 GPS Module [60]

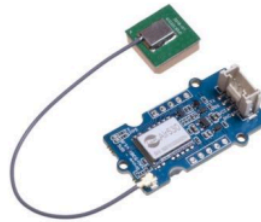


Figure 57: Grove - GPS (Air530) [61]

Final selection

Using the same logic as for the VOC sensor the chosen sensor is the PA1010D GPS Breakout.

Chosen PIC

Before selecting the final PIC, the Pin requirements need to be set, these are as seen below:

- 2 UART connections (one of these being the RS485)
- 4 analogue pins
- 1 SPI connection (for the SD card)
- 1 I2C connection
- 1 digital pin (controlling the LED for display)

Other requirements being:

- 1 USB connection (for accessing the data)
- The 8-bit MCU PIC family
- Supply of either 3.3V or 5V as these are both voltages already in use

With these requirements the PIC chosen was the "PIC18F24J50" [62] as this fit the requirements given best while not having an excessive size.

Additional requirements

Before beginning the circuit design some additional requirements must be considered, for example the conversion from RS485 to UART, this will require the use of a "MAX487" [63] or similar. This will convert the unreadable data from the RS485 to a readable UART data format.

For the supply voltage the following are required:

- LM7805 – 5V regulator
- LM1117 – 3.3V regulator

An example of a setup for a regulator can be seen in Figure 58

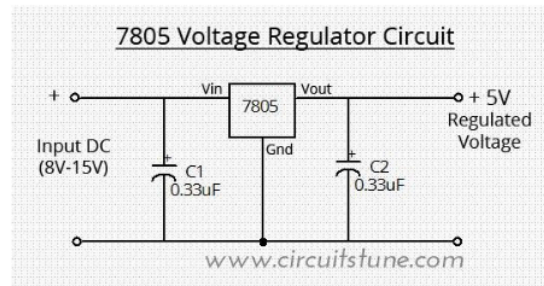


Figure 58: LM7805 setup example [64]

Then you additionally require clamps for the analogue inputs.

Additionally, there is a requirement for signal conditioning, this will be required to change the max analogue input from the Anemometer from 2V to 5V, this will require using an op amp setup, seen in Figure 59. Using the following calculation, seen in Equation 1, to find the required resistor values. With the knowledge of resistor values the best for this use case is $R_1 = 10K\Omega$ and $R_2 = 6.8K\Omega$. This will alter the 2V input to 4.94V which is as close to 5 as reasonably possible.

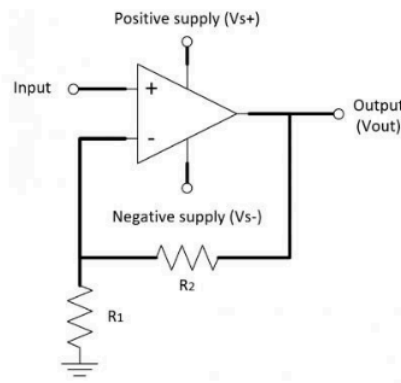


Figure 59: noninverting amplifier [65]

$$\frac{V_{out}}{V_{in}} = \text{Gain} = 1 + \frac{R_2}{R_1}$$

Equation 1: Gain of Amplifier [65]

V_{out} - voltage output

V_{in} - voltage input

R1- Resistor 1

R2- Resistor 2

Circuit diagrams

The first step before creating a circuit diagram is to create a block diagram, this is used to show the flow of data from sensors through the circuit to the SD card. Figure 60 shows a simple block diagram of how the data will be collected at the sensor and pass all the way through to the SD card. Only in certain cases will the signal processing [66] and clamps [67] be required. Signal processing is used to alter the input voltage to be equal to the desired amount, for example in this case the anemometer outputs at 0.2-2V, so in this case it will be processed to max output at 5V so more data can be collected at the ADC on the PIC. The Clamp is used to protect the PIC from spikes in voltage, this will be required on all Analogue data inputs in this case.

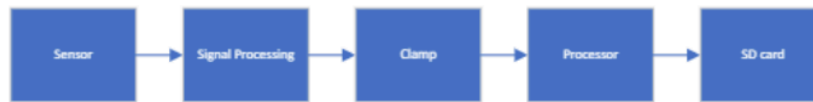


Figure 60: Block Diagram

The Circuit diagram will be created in "PROTEUS DesignSuit" [68] , once completed this will then be used to create a PCB using "EasyPC" [69].

All the requirements for the Circuit are listed below:

- PIC18F24J50 – This is the PIC being used for the data collection and saving.
- SD card – this is used for memory storage.
- USB connector – used for data to be read.
- Debugging connection – for this only 1 pin is required, this can be setup using the programmable UART port, this will can be used to program the chip while in the board.
- LM7805 regulator – This will convert the 12-Volt input to 5-Volt
- LM1117 regulator – This will convert the 12-Volt input to 3.3-Volt
- LED – this is used for a Tell to show when the PIC is operating, flashing for 1 second every 10 seconds.
- Op-Amp setup – this is used for 2->5V signal conditioning, using an TLC252C due to no requirement for negative voltage.
- Range of values of resistors used for the clamps, LED protection, Rs485 to UART conversion and I2C lines.
- Range of values of capacitors used for the clamps, regulator setups and PIC to ground.
- Diodes for the clamp.

As an additional goal when creating the PCB, the Aim will be to use different sized connectors for each external connection. This is done in the aim to prevent errors when being assembled, preventing damage to be caused to the sensors or components.

For this the proteus Diagram can be seen in Figure 61, then using this a schematic in easy PC can be created, seen in Figure 62.

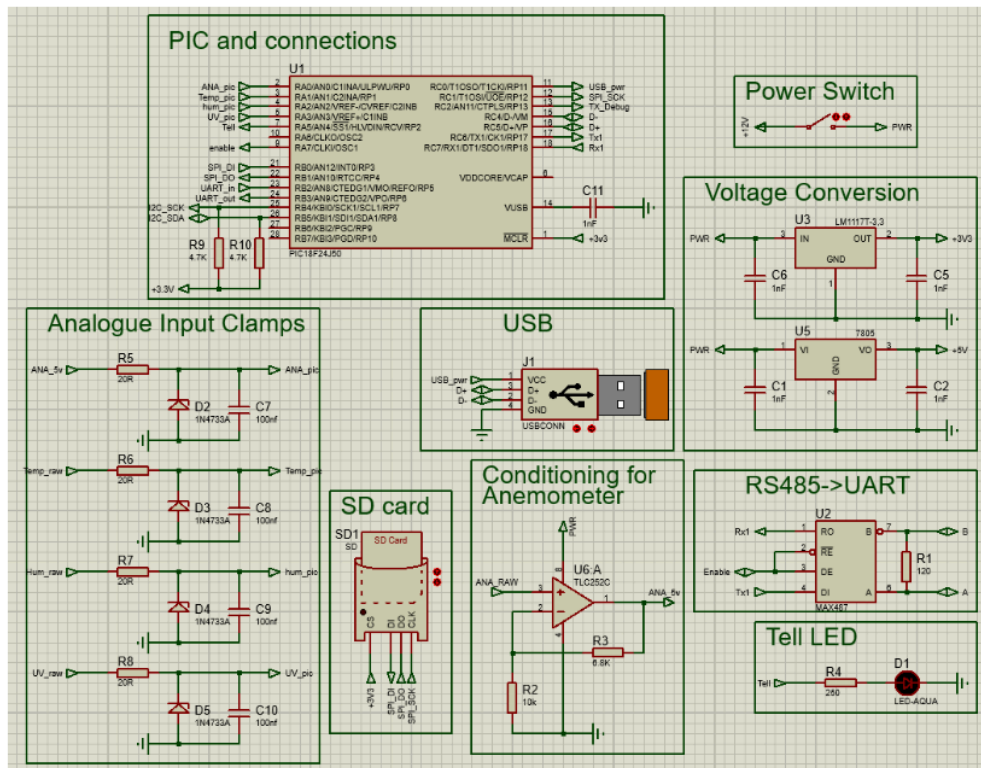


Figure 61: Proteus Schematic

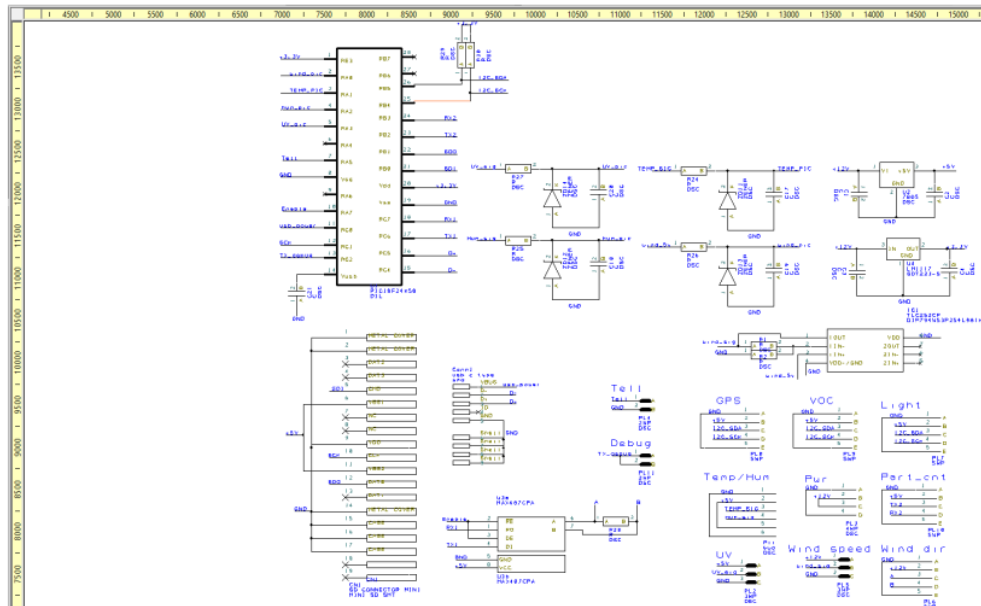


Figure 62: EasyPC Schematic

PCB Design

Using the Circuit Diagram created in Easy PC, seen in Figure 62, this is then converted to a PCB using the program, this design can be seen below in Figure 63. This image shows the completed PCB with the components placed. This is a 2 layered PCB, with the top having the components and the main connections, the bottom layer having copper pours connecting +5V, +3.3V, +12V and Ground. The final product was measured at 94x84mm.

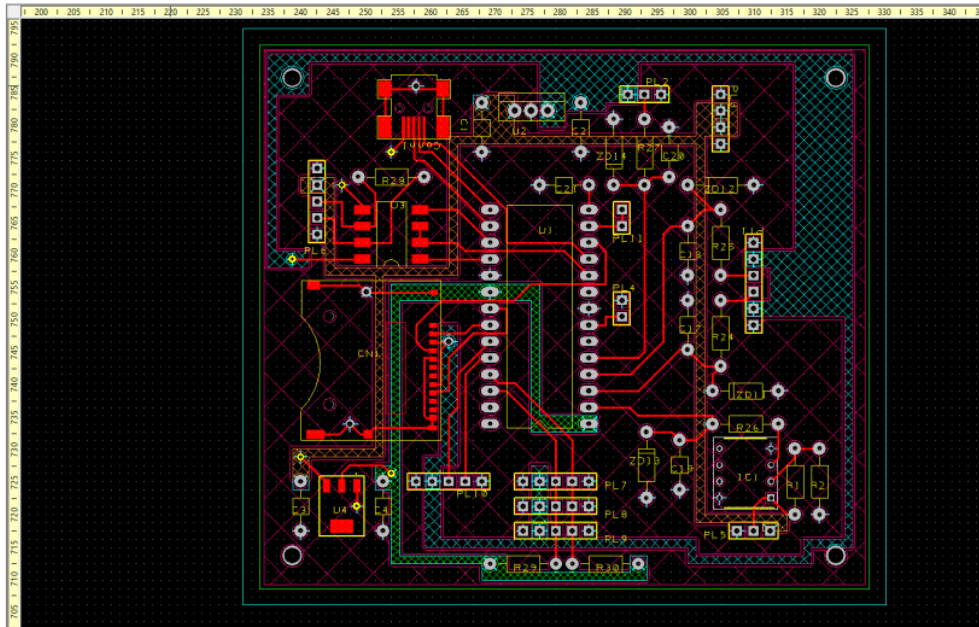


Figure 63: PCB design

Once the design was completed this was then tested using the built-in testing function, this will carry out a test looking for errors. The criteria for the test can be seen in Figure 64 and the output from this is seen in Figure 65, this clearly shows the test was passed. This means this PCB is now ready for printing, the PCB can be seen in Figure 66 and Figure 67.

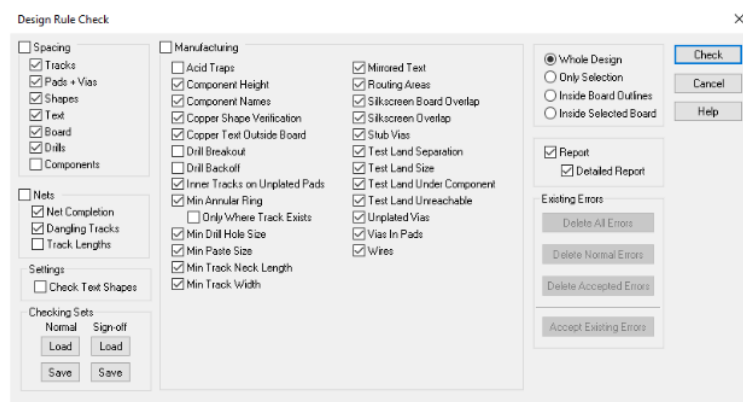


Figure 64: Design Check Rules



Figure 65: Design Rule Check Report

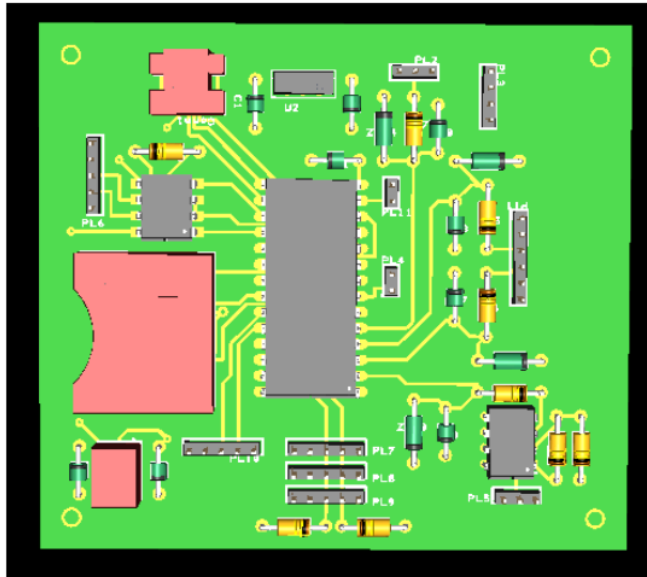


Figure 66: PCB Front

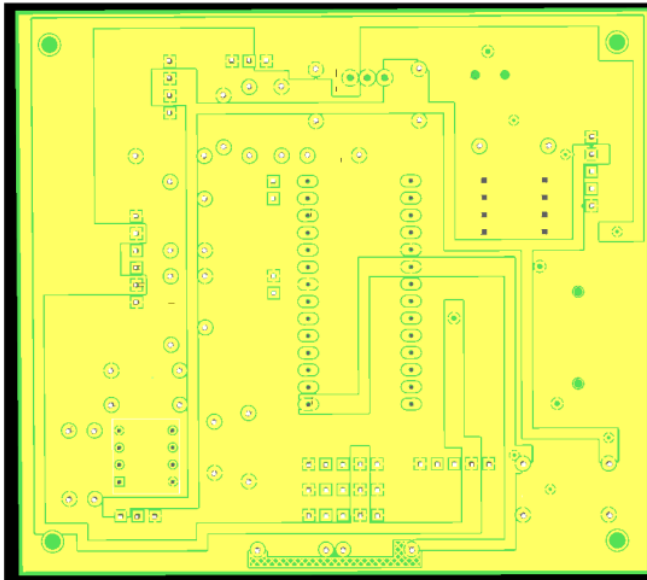


Figure 67: PCB Back

Once the testing was completed this can then be prepped for printing, this is done using the "Plotting and Printing" tool. This then creates a Gerber file which can be uploaded to a website of choice to receive a quote on Pricing for the PCB, in this case JLCPCB was used due to their low costing making 5 PCBs for £2.

Software & Data Structure

For creating a plan for the software, the best plan is to use a Flowchart [70], this allows an easy method of showing step by step how the operations will run. The Flow chart in this case can be seen in Figure 68. This shows how the main body of code will flow, Figure 69 shows the interrupt that will be used as a timer for the counts, this will allow for the data readings and the tell LED flash to be completed at the appropriate timing.

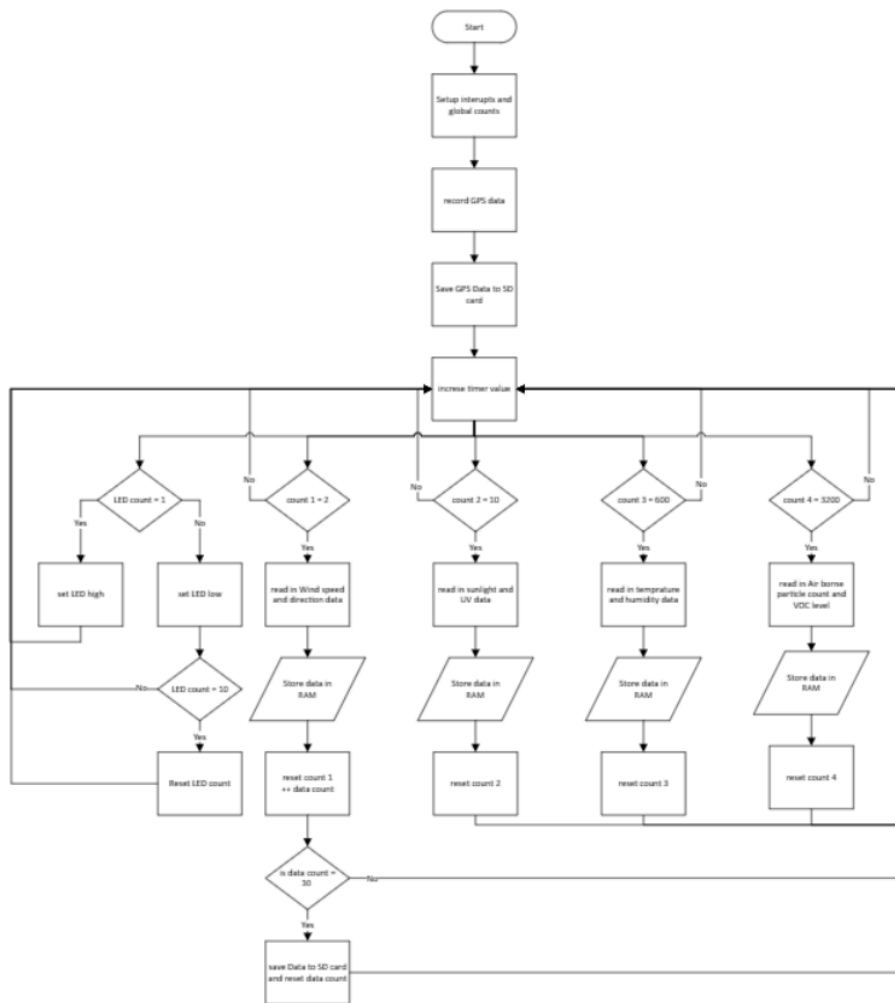


Figure 68: Main Flowchart

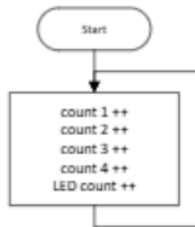


Figure 69: Interrupt

The Interrupt will be setup to be triggered every second, this means the required count can be seen bellow:

- Count 1 = 2
- Count 2 = 10
- Count 3 = 600
- Count 4 = 3200

These will allow each sensor/count to be read at the correct timing. As the data is being gathered this will be recorded and saved into a buffer, as seen in Figure 68. The data saved will be collected for a 1 minute, 60 count period, once collected this will be formatted into a package to be sent, this will lay out as seen in Figure 70. Once the package is created it will then be transmitted to the SD card using SPI [71]. Each package will be 100 Bytes of data when transmitted, apart from the first package which will additionally include 32 bytes of data, this being the GPS data.

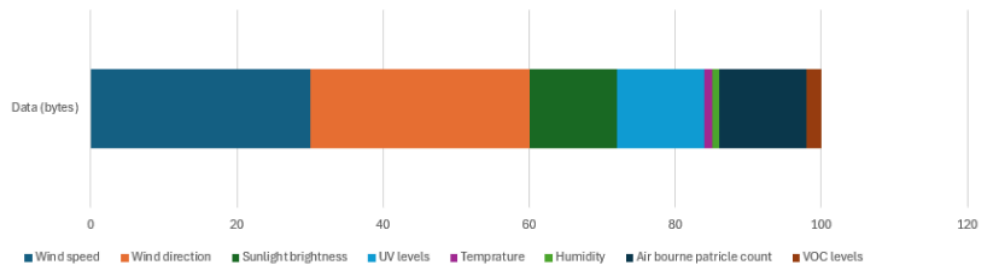


Figure 70: Data Format

With this format of data this means that the total data produced will be 2.016MB. This means a data card larger than this will be required, in this case as its more expensive to find a small SD card a 2 GB card will be used, which can be found for £7.50 on RS, this additionally means if programmed correctly this could run for much longer than 2 weeks before needing to be cleared.

Power, Enclosure, Cables and Connectors

Power

For power there are calculations for the battery requirements are needed, this can be done by calculating the current required on each voltage and then the pull that will have from a 12V battery. This can be seen in Table 20.

5V component	current required (mA)	number of components	required current (A)
temp/hum	1.2	1	0.0012
particle	10	1	0.01
light	0.7	1	0.0007
UV	1	1	0.001
VOC	2.6	1	0.0026
		5V current	0.0155
3.3V component	current required (mA)	number of components	required current (A)
pic	25	1	0.025
GPS	36	1	0.036
			0.061
12V component	current required (mA)	number of components	required current (A)
Anemometer	20	1	0.02
vane	10	1	0.01
			0.03
component	component efficiency	current required out	required current in
8705	41.66666667	0.0155	0.0372
1117	73.3	0.061	0.083219645
12V	100	0.03	0.03
		current	0.120419645
		power	1.445035744
		+1W for passive components	2.445035744
		2 weeks (W)	821.5320098
		battery size AH	68.46100082

Table 20: Battery Calculations

From this Calculations a 12V 70AH battery is required, the "Fiamm 12V Sealed Lead Acid Battery, 70Ah" [72] was then chosen using this information due to fitting this and being the cheap available option.

Enclosures

For the product it was decided to use 3 separate enclosures. 1 being the primary, this will be used to enclose the Battery, PCB and GPS. Then there will be 2 smaller cases, one used to store the sunlight level and UV sensor, another for the particle and VOC sensor. It was decided to do this for different reasons, the sunlight and UV sensors would require a case with as see through lid, then the VOC and Particle sensor will require exposure to Air, meaning a Vent system on the case will be require, this can be simply done with a few well-placed holes in the case.

For the main Enclosure there are the following requirements:

- For the Battery, PCB and GPS sensor to all fit.
- Connectors on the edge for all the connectors and a power switch.
- IP 66 rating [73]

For 2 smaller enclosures with the following requirements

- Large enough for Light and UV sensors and large enough to find the particle counter and VOC counter.
- Fit 2 connectors on side
- Clear lid for Light and UV sensors
- IP 66 rating [73] in the case of the light and UV enclosure

The conclusion for both enclosures can be seen bellow in Figure 71 and Figure 72. The first case is much larger and IP 66 rated, making it appropriate for the job. The other enclosure and be used for both setups, this comes with a clear lid and is of an appropriate sizing making it right for both use cases.



Figure 71: RS PRO Steel Wall Box, IP66, 400 mm x 400 mm x 200mm [74]



Figure 72: Fibox Grey Polycarbonate Enclosure, IP66, IP67, Clear Lid, 180 x 130 x 75mm [75]

Cables

For the cable the max size requirements are

- 4 cores
- 1A supply rating

The selected cable for this will be seen in the bill of materials. There will be a requirement for single core wire, but this can be found in the lab so will not be included in the bill of materials.

Connectors

For connectors the requirements will be

- 4 connectors
- IP 66 rating [73]

The connectors can be seen within the bill of materials, these have been selected as they were the most appropriate within the requirements.

Total Bill of Materials

Types	Name	Manufacturers number	Supplier	Quantity	Cost per unit	Total cost
Sensors	Anemometer Wind Speed Sensor w/Analog Voltage Output	ADA1733	The PI Hut	1	€ 44.80	€ 44.80
	RS485 Wind Direction Transmitter	SEN0482	The PI Hut	1	€ 43.20	€ 43.20
	TE Connectivity Temperature & Humidity Sensor, Voltage Output, Through Hole Mount, Analogue, $\pm 5\%$ RH	HPP809A031	RS	1	€ 99.23	€ 99.23
	PM55003 Particulate Matter Sensor with Cable	105770	The PI Hut	1	€ 24.50	€ 24.50
	Ambient Light Sensor(0-200klx)	SEN0390	The PI Hut	1	€ 3.00	€ 3.00
	Analog UV Light Sensor Breakout - GUVA-S12SD	ADA1918	The PI Hut	1	€ 6.50	€ 6.50
	Sensirion SGP40-D-R4, VOC Air Quality Sensor for VOC	SGP40-D-R4	RS	1	€ 2.74	€ 2.74
	PA10100 GPS Breakout	PIM525	The PI Hut	1	€ 29.70	€ 29.70
PCB/ components	PCB			1	€ 2.00	€ 2.00
	PIC18F24J50	PIC18F24J50	microchip	1	€ 2.04	€ 2.04
	Kingbright 2 V Green LED 5mm Through Hole, L-53GD, pack	47334-0001	RS	1	€ 1.07	€ 1.07
	LM7805	LM7805CT/NOPB	RS	1	€ 8.15	€ 8.15
	LM1117	LM1117MPX-18NOPB	RS	1	€ 9.50	€ 9.50
	Maxim Integrated MAX487CUA+ Line Transceiver, 8-Pin	MAX487CUA+	RS	1	€ 20.90	€ 20.90
	2GB SD card	INS02GV2	RS	1	€ 7.48	€ 7.48
	TLC252CP Texas Instruments, Op Amp, 1.7MHz, 3→ 15 V, 8-	TLC252CP	RS	1	€ 6.20	€ 6.20
	Molex, 47337 8 Way Right Angle Micro SD Memory Card Connector With Solder Termination	47334-0001	RS	1	€ 1.07	€ 1.07
	Würth Elektronik Right Angle, Surface Mount, Through Hole, Socket Type C 3.1USB Connector	632723100021	RS	1	€ 6.78	€ 6.78
	Taiwan Semi 1000V 3A, Rectifier Diode, 2-Pin DO-201AD					
	FR307G, pack of 20	FR307G	RS	1	€ 4.24	€ 4.24
	RS PRO 6.8k Ω Carbon Film Resistor 2W $\pm 5\%$, pack of 10	707-8909	RS	1	€ 2.00	€ 2.00
	RS PRO 10k Ω Carbon Film Resistor 0.25W $\pm 5\%$, pack of 10	707-7745	RS	1	€ 1.41	€ 1.41
	20 ohm resistor pack of 5	YR1B20RCC	RS	1	€ 2.60	€ 2.60
	RS PRO 250 Ω Metal Film Resistor 0.6W $\pm 0.5\%$, pack of 50	174-2772	RS	1	€ 5.30	€ 5.30
	RS PRO 4.7k Ω Carbon Film Resistor 0.25W $\pm 5\%$, pack of 10	707-7726	RS	1	€ 1.27	€ 1.27
	TE Connectivity 120 Ω Metal Film Resistor 0.25W $\pm 0.1\%$					
	UPF25B120RV	UPF25B120RV	RS	1	€ 4.87	€ 4.87
	KEMET 100nF Multilayer Ceramic Capacitor MLCC, 50V dc V, $\pm 10\%$, Through Hole, pack of 5	C322C104K5R5TA	RS	1	€ 1.13	€ 1.13
	$\pm 10\%$ S3N Dielectric, F, Through Hole +125 C Max Op. Temp. pack of 10	F102K53S3NR63K7R	RS	1	€ 4.38	€ 4.38
box/ connectors	Alpha Wire Alpha Essentials Communication & Control Control Cable, 4 Cores, 0.56 mm ² , Screened, 30m, Grey PVC Sheath,	2414C SL005	RS	1	€ 71.72	€ 71.72
	Mount MLL Spec Circular Connector, Pin Contacts, Shell Size 14S	MS3106A-14S-2P	RS	9	€ 25.84	€ 232.56
	Amphenol Industrial, MS3102A, Copper Alloy 4 Way Box					
	Mount MLL Spec Circular Connector Receptacle, Socket	MS3102A-14S-2S	RS	9	€ 15.74	€ 141.66
	RS PRO SPST, On-Off Rocker Switch Panel Mount	419-744	RS	1	€ 7.84	€ 7.84
	RS PRO Steel Wall Box, IP66, 400 mm x 400 mm x 200mm	303-31-708	RS	1	€ 81.01	€ 81.01
	Fibox Grey Polycarbonate Enclosure, IP66, IP67, Clear Lid, 180 x 130 x 75mm	PCM 150/75 T ENCLOSURE	RS	2	€ 32.53	€ 65.18
PSU	Fiamm 12V Sealed Lead Acid Battery, 70Ah	12FGL70/L	RS	1	€ 331.50	€ 331.50
					Total cost	€ 1,283.53

Table 21: Bill of Materials

Table 21 shows the Total Cost of the Project as £1,283.53. For the main components the Data sheets can be found below in the Appendix.

Future upgrades

For future upgrades, there are a few things that could be considered when looking at the current market. One option would be to add the ability to monitor rain levels using a rain gauge, this would be another form of weather to tracked by the system allowing for better data gathering. Another consideration would be to create a method of live viewing, meaning that there is a Wi-Fi/Bluetooth enabled or even GPRS/GSM if the unit is setup far away from

the user. A live connection to the unit which would allow for a user to view the data at any time rather than having to extract the data from the unit. Finally, a method of linking together multiple units, meaning that there could be a range of setups to gather a more accurate picture of the weather. This would mean that the Data would give a more accurate picture of the weather, removing anomalies that may occur in one location.

Appendix

Components datasheet links

Anemometer Wind Speed Sensor w/Analog Voltage Output - [Anemometer Wind Speed Sensor w/Analog Voltage Output | The Pi Hut](#)

RS485 Wind Direction Transmitter - [RS485 Wind Direction Transmitter | The Pi Hut](#)

TE Connectivity Temperature & Humidity Sensor, Voltage Output, Through Hole Mount, Analogue, $\pm 5\%RH$ - [HPP809A031 | TE Connectivity Temperature & Humidity Sensor, Voltage Output, Through Hole Mount, Analogue, \$\pm 5\%RH\$ | RS](#)

PMS5003 Particulate Matter Sensor with Cable - [PMS5003 Particulate Matter Sensor with Cable | The Pi Hut](#)

Ambient Light Sensor(0-200klx) - [Ambient Light Sensor\(0-200klx\) | The Pi Hut](#)

Analog UV Light Sensor Breakout - GUVA-S12SD - <https://thepihut.com/products/adafruit-analog-uv-light-sensor-breakout-guva-s12sd>

Sensirion SGP40-D-R4, VOC Air Quality Sensor for VOC Monitors - [Sensirion SGP40-D-R4, VOC Air Quality Sensor for VOC Monitors | RS](#)

PA1010D GPS Breakout - [PA1010D GPS Breakout | The Pi Hut](#)

PIC18F24J50 - microchip.com/en-us/product/PIC18F24J50#product-purchase

LM7805 - [LM340, LM340A and LM7805 Family Wide VIN 1.5-A Fixed Voltage Regulators datasheet \(Rev. L\)](#)

LM1117 - [LM1117 800-mA, Low-Dropout Linear Regulator datasheet \(Rev. Q\)](#)

Max487 - [MAX481 DS](#)

TLC252CP Texas Instruments, Op Amp, 1.7MHz, 3 $\rightarrow$ 15 V, 8-Pin PDIP - [tlc25l2a.pdf \(ti.com\)](#)

Fiamm 12V Sealed Lead Acid Battery, 70Ah - [A700000006437184.pdf](#)

References

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FINAL GRADE

GENERAL COMMENTS

74/100

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SAM LLOYD

73.80

RESEARCH-INFORMED LITERATURE

-  Reasonable literature review of available systems with a good comparison of relevant information but a short section of the manufacturers specification would have improved it. 68%
- 6.8**

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. Your PCB is very good with zero errors. 76%
- 19**

ANALYSIS

-  Good selection of microcontroller. Good selection of components well described and selected via the tables.. Reasonable case selection but would have been better served with a more rugged design. Good selection of connectors .72%
- 25.2**

PRACTICAL APPLICATION AND DEP.



Costings were included in a table without an image but with the manufactures name and part number, supplier's name. Good attempt at future enhancements. 76%

15.2

SKILLS FOR PROFESSIONAL PRAC.



The report is well presented with a very good selection of references. 76%

7.6