

# 14 Day Weather/ Air Quality Measurement System

Electronics Systems Design

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## 1. Introduction

This report will cover the theoretical and practical aspects of a system design project. The design is based around a micro controller-based portable air and weather monitoring system which is aimed towards an amateur weather forecast enthusiast. The system will focus on monitoring UV levels, Sunlight brightness, temperature & humidity, wind speed, VOC levels, air borne particle count and GPS positioning. To monitor these areas components will be chosen to be suitable for the extreme environmental conditions, calculations will also be made to justify microcontroller selection, battery capacity, memory capacity etc. The report will continue onto illustrating the schematic and PCB design of the system with finalising on a build cost and suggested improvements for the next design. The system will need to be practically sound for the user and as cost effective as possible while ensuring the final product is as accurate and reliable.

## 2. Literature review

### 2.1 Topic Research

Weather data acquisition system technology is used to collect, process, and analyse weather-related information. It involves the use of various sensors, instruments, and communication networks to gather data on temperature, humidity, wind speed, precipitation, and other meteorological parameters.

The system's aim is to provide accurate and well-timed weather data for forecasting, research, and other applications. It plays an important role in meteorology, climate studies, agriculture, aviation, and many other industries that rely on weather information.

Weather data acquisition systems often consist of weather stations or weather sensors placed at different locations. These sensors measure specific weather parameters and transmit the collected data to a data logger. The data logger then processes and stores the information for further analysis.

Communication networks, such as satellite links or internet connections, are used to transfer the collected data from remote weather stations to a central database or meteorological organizations. This allows for real-time monitoring and analysis of weather conditions.

In recent years, advancements in technology have led to the development of automated weather stations and remote sensing techniques. These systems can collect data continuously and provide more detailed and thorough weather information [1].

## 2.2 Existing Systems

|                                                                                                                                                                                                                                                                                                                                                     |                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|  <p>Figure 1</p>                                                                                                                                                                                                                                                   |  <p>Figure 2</p>                                                                                                                                                                                                                                    |  <p>Figure 3</p>                                                                                                                                                                                                                                                                                                                                       |
| <p>[2] HOBO Cellular Weather Station Kit</p>                                                                                                                                                                                                                                                                                                        | <p>[3] Met Connect Weather Station</p>                                                                                                                                                                                                                                                                                               | <p>[4] Weather Station PCE-FWS20N</p>                                                                                                                                                                                                                                                                                                                                                                                                     |
| <ul style="list-style-type: none"> <li>• Cloud-based 24/7 data access via HOBOLink web-enabled software platform</li> <li>• 4G cellular communication (also works with 3G/2G)</li> <li>• Solar powered</li> <li>• Plug-and-play operation</li> <li>• Alert notifications via text/email</li> <li>• Rugged double-weatherproof enclosure.</li> </ul> | <ul style="list-style-type: none"> <li>• 10 reference quality parameters.</li> <li>• Allows the wind sensor to be mounted away from the base station.</li> <li>• Temperature Input for Ground Temperature</li> <li>• Dew Point Measurement</li> <li>• Barometric Pressure Measurement</li> <li>• Compact&amp; lightweight</li> </ul> | <ul style="list-style-type: none"> <li>• Software for analysing the stored data.</li> <li>• Backlit 7-inch touch screen</li> <li>• Weather forecast function.</li> <li>• Automatic time setting thanks to DCF.</li> <li>• Adjustable alarms when the measured value is exceeded.</li> <li>• Wind direction and wind speed</li> <li>• Temperature and humidity display</li> <li>• Solar panel on the outdoor unit to the supply</li> </ul> |

Table 1

### 3. Component Selection

To measure each specified property regarding the weather a sensor will need to be chosen, this being said there are many different types of sensors that can measure each weather property, a comparison table will need to be completed in order to determine the best suited sensor for each measurement.

#### 3.1 Parameter selection

The following table states suitable ranges and number of bytes that the sensors will need to be compatible with.

| <u>Type of input</u> | <u>Parameter for measurement</u> | <u>Reference for Units</u> | <u>Measured Unit</u> | <u>Max Values</u> | <u>Resolution</u> | <u>No. of possible variables</u> | <u>No. of bits</u> | <u>No. of Bytes</u> |
|----------------------|----------------------------------|----------------------------|----------------------|-------------------|-------------------|----------------------------------|--------------------|---------------------|
| <u>Analogue</u>      | UV Levels (UVA-UVB-UVC)          | [5]                        | W/ M <sup>2</sup>    | 0-400nm           | 1nm               | 400                              | 9                  | 2                   |
| <u>Analogue</u>      | Air borne particle               |                            | ug / M <sup>3</sup>  | 0-1000            | 1                 | 1000                             | 10                 | 2                   |
| <u>Analogue</u>      | Wind Speed                       | [6]                        | MPH                  | 0-100             | 1                 | 100                              | 7                  | 1                   |
| <u>Analogue</u>      | Direction                        | -                          | Degrees              | 0-360             | 1                 | 360                              | 9                  | 2                   |
| <u>Digital</u>       | VOC Levels                       | [7]                        | PPB                  | 0-6000            | 10                | 600                              | 10                 | 2                   |
| <u>Analogue</u>      | Humidity                         | -                          | %                    | 0-100             | 1                 | 100                              | 7                  | 1                   |
| <u>Analogue</u>      | Temperature                      | -                          | °C                   | -80 to +60        | 1                 | 140                              | 8                  | 1                   |
| <u>Analogue</u>      | Sunlight Brightness              | [8]                        | nm                   | 380-700           | 1                 | 320                              | 9                  | 2                   |
|                      |                                  |                            |                      |                   |                   |                                  |                    |                     |

Table 2

## 3.2 Sensor Selection

### 3.2.1 UV Levels

UV levels measurements are taken to measure the amount of ultraviolet radiation is in the air, [9] states that there are many different sensors that have the attributes to measure UV. The following table is a comparison of various types of sensors that can measure UV Levels.

| <u>Manufacturer</u>          | <u>Reference</u> | <u>Part No.</u>               | <u>Material</u>                    | <u>Operating Temperature</u><br>(°C) | <u>Protection Rating</u> | <u>Supply Voltage</u>                  | <u>Output Signal</u>                           | <u>Power Consumption</u>                                                     | <u>Wavelength Range</u>                                            | <u>Cost</u>  |
|------------------------------|------------------|-------------------------------|------------------------------------|--------------------------------------|--------------------------|----------------------------------------|------------------------------------------------|------------------------------------------------------------------------------|--------------------------------------------------------------------|--------------|
| <b>SG Lux</b>                | [10]             | UV Cosine                     | TEFLON(PTFE),<br>SS 20mm<br>THREAD | -20 TO +80                           | IP68/67                  | 24 VDC                                 | 4-20mA                                         | = signal out(<br>The current is<br>proportional<br>to<br>the<br>irradiance.) | UV, UVA,<br>UVB+C,<br>UVC, UV-<br>Index,<br>Bluelight or<br>UV+VIS | €275/£236.44 |
| <b>SG LUX</b>                | [11]             | TOCON<br>_UVI                 | TEFLON(PTFE),<br>SS ¼ THREAD       | -25 TO +85                           | IP65                     | 7-<br>24VDC<br><br>Or<br>2.5 –<br>5VDC | 0 –<br>4.75VDC                                 | 150 µA                                                                       | Index                                                              | €248         |
| <b>Davis<br/>Instruments</b> | [12]             | UV<br>Sensor<br>- SKU<br>6490 | UV-resistant<br>ABS plastic        | -40 TO +65                           |                          | 3V +/-<br>10%                          | 0-<br>2.5VDC<br><br>(150mV<br>per UV<br>Index) | 2.4mA                                                                        | 280 to 360<br>nm                                                   | \$425        |

Table 3

The SG Lux UV cosine sensor proves to be the most suitable sensor in comparison to the other two sensors. The UV cosine sensor can measure all bands of the UV spectrum which will allow the user to achieve a full insight into each wavelength range while the other two sensors have got less capabilities regarding measurement characteristics. The UV cosine is also at a reasonable price considering the package that is provided with the UV cosine sensor.



Figure 4

## 3.2.2 Sunlight Brightness

| <u>Manufacturer</u>            | <u>Reference</u> | <u>Part No.</u> | <u>Material</u>                                          | <u>Protection Rating</u> | <u>Supply Voltage</u>      | <u>Output Signal</u>                        | <u>Power Consumption (mA)</u>                                                          | <u>Accuracy</u>                     | <u>Range</u>                      | <u>Cost</u> |
|--------------------------------|------------------|-----------------|----------------------------------------------------------|--------------------------|----------------------------|---------------------------------------------|----------------------------------------------------------------------------------------|-------------------------------------|-----------------------------------|-------------|
| <b><u>Omni Instruments</u></b> | [13]             | LL-P-V          | PC/GF<br>(Halogen free, flame retardant & UV stabilised) | IP65                     | 24vAC/DC<br>( $\pm 10\%$ ) | 0-10V                                       | -                                                                                      | $\pm 5\%$ across range              | 10-2,000 Lux<br><br>10-10,000 Lux | £62.61      |
| <b><u>Apogee</u></b>           | [14]             | SP-214-SS       | anodized aluminium housing, Silicone                     | IP67                     | 7 to 24 V DC               | 4 to 20 mA                                  | Maximum of 22 mA (2 mA quiescent)                                                      | Less than 1 %                       | 360 to 1120 nm                    | £298        |
| <b><u>Kipp &amp; Zonen</u></b> | [15]             | CSD-3           | Glass, plastic                                           | IP65                     | 0.1 W at 12 VDC (9-15 VDC) | mV/Wm <sup>2</sup> (direct solar radiation) | 1 $\pm$ 0.1 W at 12 VDC (dew removal), 10 $\pm$ 1 W at 12 VDC (frost and snow removal) | > 90% (direct signal for clear sky) | 400 to 1100 nm                    | £2166       |

Table 4

The Apogee SP-214-SS proves to be the most suitable from the comparison table as it has a low deviation in accuracy compared to the other while also having a good range for measurement, the IP rating also supersedes the other two sensors which will benefit the environmental conditions that the station will be in when in use.



Figure 5

## 3.2.3 Temperature &amp; Humidity

| <u>Manufacturer</u>                                          | <u>Reference</u> | <u>Part No.</u> | <u>Material</u>                  | <u>Protection Rating</u> | <u>Supply Voltage</u> | <u>Output Signal</u>                                                                            | <u>Power Consumption (mA)</u> | <u>Accuracy</u>                                                                                              | <u>Range</u>                            | <u>Cost</u> |
|--------------------------------------------------------------|------------------|-----------------|----------------------------------|--------------------------|-----------------------|-------------------------------------------------------------------------------------------------|-------------------------------|--------------------------------------------------------------------------------------------------------------|-----------------------------------------|-------------|
| <b>Industrial temperature and humidity sensor wall mount</b> | [16]             | RS-WS-* -2-*    | ABS Plastic                      | IP65                     | 10-30 VDC             | RS486/4-20mA/0-5V/0-10V                                                                         | -                             | $\pm 2\%RH$ ,<br>$\pm 0.4^{\circ}C(25^{\circ}C)$                                                             | RH = 0-100%<br><br>Temp = -40 to +80°C  | \$25.16     |
| <b>Ahlborn</b>                                               | [17]             | FHAD 36 Rax     | Polycarbonate<br>Stainless steel | IP65                     | 6 to 19VDC            | Voltage                                                                                         | 9                             | $\pm 1.3\% RH$ (at +23°C $\pm 5\% K$ )                                                                       | RH = 0-95%<br><br>Temp = -100 to +170°C | £700        |
| <b>Vaisala</b>                                               | [18]             | HMP155          | Polycarbonate<br>Stainless steel | IP66                     | 7 to 28VDC            | : 0 ... 1 V, 0 ... 5 V,<br>0 ... 10 V<br><br>Resistive Pt100<br>4-wire connection<br><br>RS-485 | 3                             | $\pm(1.0 + 0.008 \times \text{reading})\%RH$<br><br>$\pm(0.226 - 0.0028 \times \text{temperature})^{\circ}C$ | RH = 0-100%<br><br>Temp = -80 to +60°C  | £168        |

Table 5

In relation to the temperature and humidity sensor, the Vaisala sensor proved to be the most suitable for the application since [19] M. Özgür Nevres states that the hottest recorded temperature on the planet is 54.4°C and the coldest recorded temperature on the planet is -98°C. Considering these are extreme temperatures, the Vaisala can measure temperatures of -80 to +60 °C these thresholds for measuring are more than acceptable since the probability of the temperatures exceeding these are very low. The Vaisala also has a lower power consumption in relation to the other two sensors.



Figure 6

## 3.2.4 Wind Speed &amp; Direction

| <u>Manufacturer</u>      | <u>Reference</u> | <u>Part No.</u>                     | <u>Material</u>                              | <u>Protection Rating</u> | <u>Supply Voltage</u> | <u>Output Signal</u> | <u>Power Consumption (mA)</u> | <u>Accuracy</u>                                                                      | <u>Range</u>                                     | <u>Cost</u> |
|--------------------------|------------------|-------------------------------------|----------------------------------------------|--------------------------|-----------------------|----------------------|-------------------------------|--------------------------------------------------------------------------------------|--------------------------------------------------|-------------|
| <u>Davis Instruments</u> | [20]             | SKU 6415                            | Polyaceta<br>&<br>Clear-anodized<br>aluminum | IP65                     | Self-<br>powered      |                      | N/A                           | Direction=<br>$\pm 4^\circ$<br><br>Speed = $\pm 2$<br>mph                            | 0-89 mph<br><br>Wind – 16 points                 | \$650       |
| <u>Wind Ultra</u>        | [21]             | Compact<br>Ultrasonic<br>Anemometer | Thermoplastic<br>& Stainless<br>Steel        | IP69K                    | 5-30VDC               | RS485                | N/A                           | Direction= -<br>>20 m/s<br><br><2° RMSE<br><br>Speed = 0-<br>>20 m/s<br><br><3% RMSE | Wind speed 0-75m/s<br><br>Wind direction- 0-360° | £1,699      |
| <u>Renekeer</u>          | [22]             | RS-CFSFX-*-2                        | Plastic/<br>aluminium                        | IP66                     | 10-30VDC              | 4-20mA               | 2mA                           | Direction=<br>$\pm 3^\circ$<br><br>Speed =<br>$\pm 0.2$ m/s                          | Wind speed -60m/s<br><br>Wind direction- 0-359°  | \$188.7     |

Table 6

The three wind sensors all have good specifications, the Renekeer proves to be the best suited for this system due to cost and power consumption beating the other two choice when compared.



Figure 7

## 3.2.5 Air Borne Particle Count

| <u>Manufacturer</u> | <u>Reference</u> | <u>Part No.</u> | <u>Material</u>          | <u>Protection Rating</u> | <u>Supply Voltage</u> | <u>Output Signal</u>                                  | <u>Power Consumption (mA)</u>           | <u>Accuracy</u>                                                                          | <u>Range</u>                                                                                            | <u>Cost</u> |
|---------------------|------------------|-----------------|--------------------------|--------------------------|-----------------------|-------------------------------------------------------|-----------------------------------------|------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------|-------------|
| <b>Honeywell</b>    | [23]             | C7363A          | ABS Plastic              | IP30                     | 24VAC/DC              | 4-20 mA (sourcing) or 0-5 Vdc / 0-10 Vdc (selectable) | 75 mA @ 24 Vdc, 100 mA max @ 24 Vac     | ±10 µg/m <sup>3</sup> (0 – 100 µg/m <sup>3</sup> ), ±10% (100 – 1000 µg/m <sup>3</sup> ) | 0-1000 µg/m <sup>3</sup>                                                                                | \$626.10    |
| <b>Panasonic</b>    | [24]             | SN-GCJA5        | ABS Plastic              | N/A                      | DC5V +/- 10%          | I2C & UART (TTL)                                      | Below 100mA                             | ±10%<br>35µg/m <sup>3</sup><br><,<br><1,000µg/m <sup>3</sup>                             | 0µg/m <sup>3</sup> – 2,000µg/m <sup>3</sup> (UART)<br>0µg/m <sup>3</sup> – X,XXXµg/m <sup>3</sup> (I2C) | \$22.415    |
| <b>Greystone</b>    | [25]             | PMOS SERIES     | Polycarbonate, (NEMA 4X) | IP65                     | 24 Vac/dc ±20%        | 4-20 mA (sourcing) or 0-5 Vdc / 0-10 Vdc (selectable) | 75 mA max @ 24 Vdc, 100 mA max @ 24 Vac | ±10 ug/m <sup>3</sup> (0 – 100 ug/m <sup>3</sup> ), ±10% (100 – 1000 ug/m <sup>3</sup> ) | 0 – 1000 ug/m <sup>3</sup>                                                                              | £610.80     |

Table 7

The three air particle sensors that have been compared all have good specification. The Greystone PMOS Series proves to suit the design best since the protection rating of the enclosure is suited to external use, resulting in the sensor being suited for external use which will help gain true readings, on the other hand if the other two sensors were used externally, they would have to be installed in a waterproof enclosure which would then result in false readings.



Figure 8

## 3.2.6 VOC Level

| <u>Manufacturer</u>          | <u>Reference</u> | <u>Part No.</u>  | <u>Material</u>          | <u>Protection Rating</u> | <u>Supply Voltage</u> | <u>Output Signal</u>                                                       | <u>Power Consumption (mA)</u> | <u>Accuracy</u>                                      | <u>Range</u>    | <u>Cost</u> |
|------------------------------|------------------|------------------|--------------------------|--------------------------|-----------------------|----------------------------------------------------------------------------|-------------------------------|------------------------------------------------------|-----------------|-------------|
| <b><u>Aeroqual</u></b>       | [26]             | Series 930       | Polycarbonate/<br>NEMA 2 | IP41                     | (range 22-24 Vdc)     | 4-20 mA (opto-isolated),<br>12-24 Vdc                                      | 500mA                         | N/A                                                  | N/A             | N/A         |
| <b><u>Sensirion</u></b>      | [27]             | SGP41            | N/A                      | N/A                      | +1.7 to +3.6 V        | I2C                                                                        | 3.2 mA @3.3V                  | <±5 VOC Index points<br>or<br>% m.v.<br>(the larger) | 0-1'000'000 PPB | £8.64       |
| <b><u>SGX Sensortech</u></b> | [28]             | PS1-VOC-1000-MOD | PPO                      | N/A                      | 3.3-5.5V DC           | 3.3V UART digital signal/:<br>VCC- Red, GND- Black, RX- Yellow, TX- Green/ | < 5mA/ 25mW @ 5V DC           | ± 5% F.S                                             | 0 – 1000ppm     | £88.32      |

Table 8

The Sensirion and the SGX sensors both have similar specifications, both will need a positive airflow to gain true readings of the outside VOC levels, resulting in a fan being installed on the enclosure, the sensirion is at a cheaper cost which will be cost effective to the overall cost of the design.



Figure 9

## 3.2.7 GPS Position

| <u>Manufacturer</u> | <u>Reference</u> | <u>Part No.</u> | <u>Material</u>             | <u>Protection Rating</u> | <u>Supply Voltage</u> | <u>Output Signal</u> | <u>Power Consumption (mA)</u> | <u>Accuracy</u>                   | <u>Cost</u> |
|---------------------|------------------|-----------------|-----------------------------|--------------------------|-----------------------|----------------------|-------------------------------|-----------------------------------|-------------|
| <u>Garmin</u>       | [29]             | GPS16X-HVS      | Polycarbonate thermoplastic | IPX7                     | 8 to 40 VDC           | 0-5V /RS232          | 65 @ 12VDC                    | 0.1 knot RMS steady state/ < 15 m | £122        |
| <u>ST</u>           | [30]             | Teseo-VIC3DA    | -                           | -                        | 3.3 V                 | I2C, UART            | 48.8                          | <1.5 m                            | £20.83      |
| <u>Quectel</u>      | [31]             | L76             | -                           | -                        | 1.5 to 4.5 VDC        | TXD1 & RXD1 UART     | 40                            | <2.5 m CEP @ -130dBm              | £9.439      |

Table 9

The three sensors that have been compared all have similar specifications, the Quectel sensor proves to be more suitable for the design since it can be mounted onto the PCB while also being cost effective.



Figure 10

### 3.3 Connector Specification

#### 3.3.1 External Panel Cable Connections

|                                                                                                                          |              |                                                                                                              |              |                                                                                                                                      |               |                                                                                                                          |              |                                                                                                    |          |                                                                                        |               |
|--------------------------------------------------------------------------------------------------------------------------|--------------|--------------------------------------------------------------------------------------------------------------|--------------|--------------------------------------------------------------------------------------------------------------------------------------|---------------|--------------------------------------------------------------------------------------------------------------------------|--------------|----------------------------------------------------------------------------------------------------|----------|----------------------------------------------------------------------------------------|---------------|
|                                         |              |                             |              |                                                     |               |                                        |              |                 |          |     |               |
| Figure 11                                                                                                                |              | Figure 12                                                                                                    |              | Figure 13                                                                                                                            |               | Figure 14                                                                                                                |              | Figure 15                                                                                          |          | Figure 16                                                                              |               |
| <b>[32] 3 Pin Panel mount connector</b>                                                                                  |              | <b>[33] 3 Pin Cable Connector</b>                                                                            |              | <b>[34] 4 Pin Panel mount connector</b>                                                                                              |               | <b>[35] 4 Pin Cable Connector</b>                                                                                        |              | <b>[36] 5 Pin Panel mount connector</b>                                                            |          | <b>[37] 5 Pin Cable Connector</b>                                                      |               |
| IP68                                                                                                                     | Cost = £7.88 | IP68                                                                                                         | Cost = £7.88 | IP68                                                                                                                                 | Cost = £12.43 | IP68                                                                                                                     | Cost= £12.43 | IP68                                                                                               | Cost=£23 | IP68                                                                                   | Cost = £20.04 |
| This Panel mount connector will be used for the UV Level Sensor and the Airborne Particle Sensor entering the enclosure. |              | This connector will be used for the UV Level Sensor and the Airborne Particle Sensor entering the enclosure. |              | This Panel mount connector will be used for the Wind speed & direction and the temperature & humidity Sensor entering the enclosure. |               | This connector will be used for the Wind speed & direction and the temperature & humidity Sensor entering the enclosure. |              | This Panel mount connector will be used for the Sunlight Brightness Sensor entering the enclosure. |          | This connector will be used for the Sunlight Brightness Sensor entering the enclosure. |               |

Table 10

#### 3.3.2 PCB Connectors

The connectors that have been chosen for the PCB board are Molex connectors as illustrated in the figure below, the cost is £8.81p. [38]



Figure 17

3.4 Power UP System & Start Including LED Indication

|                                                                                                                                                                       |               |                                                                                    |              |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|------------------------------------------------------------------------------------|--------------|
|                                                                                      |               |  |              |
| <i>Figure 18</i>                                                                                                                                                      |               | <i>Figure 19</i>                                                                   |              |
| <b>[39] ON/OFF Key Switch</b>                                                                                                                                         |               | <b>[40] Start Button</b>                                                           |              |
| IP65                                                                                                                                                                  | Cost = £19.40 | IP65                                                                               | Cost = £3.35 |
| This Key switch will be used to turn on the system, by having a key switch it will allow the user to leave the system unattended while knowing the system is kept on. |               | This Start button will be used to start the measurements.                          |              |

Table 11

|                                                                                                               |      |                                                                                              |      |
|---------------------------------------------------------------------------------------------------------------|------|----------------------------------------------------------------------------------------------|------|
|                            |      |          |      |
| <i>Figure 20</i>                                                                                              |      | <i>Figure 21</i>                                                                             |      |
| <b>[41] RS Components Green LED</b>                                                                           |      | <b>[42] RS Components Red LED</b>                                                            |      |
| Cost = £2.88                                                                                                  | IP65 | Cost = £2.88                                                                                 | IP65 |
| The Green LED will be mounted to the front of the panel to indicate the measuring is running. <i>Table 12</i> |      | The Red LED will be mounted to the front of the panel to indicate the system is switched on. |      |

### 3.5 Battery Specification

| <b>Battery Specifications</b>            |                                      |                        |                                       |
|------------------------------------------|--------------------------------------|------------------------|---------------------------------------|
| <b><u>Component</u></b>                  | <b><u>Power Consumption (mA)</u></b> | <b><u>Quantity</u></b> | <b><u>Total Power Consumption</u></b> |
| <b><u>UV Levels (UVA-UVB-UVC)</u></b>    | 30                                   | 1                      | 30                                    |
| <b><u>Air borne particle</u></b>         | 100                                  | 1                      | 100                                   |
| <b><u>Wind Speed &amp; Direction</u></b> | 2                                    | 1                      | 2                                     |
| <b><u>VOC Levels</u></b>                 | 3.2                                  | 1                      | 3.2                                   |
| <b><u>Temperature &amp; Humidity</u></b> | 3                                    | 1                      | 3                                     |
| <b><u>GPS Position</u></b>               | 40                                   | 1                      | 40                                    |
| <b><u>Sunlight Brightness</u></b>        | 22                                   | 1                      | 22                                    |
| <b><u>LED</u></b>                        | 20                                   | 2                      | 40                                    |
| <b><u>Mini Panel Fan</u></b>             | 42                                   | 1                      | 42                                    |
| Total =                                  |                                      |                        | 282.2 mAH                             |
| X 24 hours =                             |                                      |                        | 6772.8 mAH                            |
| X 14 Days =                              |                                      |                        | 94819.2 mAH                           |

Table 13

The total Power consumption of all components is 94.8192 AH. This is if the system was constantly taking all measurements 24 hours a day for the full 14 days.

### 3.6 Battery Selection

The chosen battery that will be suitable for the system is shown in the table below.

|                                                                                     |                |
|-------------------------------------------------------------------------------------|----------------|
|  |                |
| Figure 22                                                                           |                |
| [43] 24V 100Ah Core Series Lithium Iron Phosphate Battery                           |                |
| IP65                                                                                | Cost = £619.99 |
| Weight = 21Kg                                                                       |                |

Table 14

3.7 Enclosure Selection

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |      |                                                                                                                                                                                               |                                                                                                                                                                                                                                        |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                                                                                                                                                                                                                                                                                                                                                                         |      |                                                                                                             |                                                                                                                                                     |
| <i>Figure 23</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |      | <i>Figure 24</i>                                                                                                                                                                              | <i>Figure 25</i>                                                                                                                                                                                                                       |
| <b>[44] <u>Rittal CS Wall-mounted Outdoor enclosure</u></b>                                                                                                                                                                                                                                                                                                                                                                                                                                                              |      | <b>[45] <u>Rittal Pole clamp set (2 pieces)</u></b>                                                                                                                                           | <b>[46] <u>Davis EZ-Mount Tripod</u></b>                                                                                                                                                                                               |
| Price = £620                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | IP65 | Price = £71.28                                                                                                                                                                                | £156.14                                                                                                                                                                                                                                |
| Dimensions = 370x522x210 mm                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |      |                                                                                                                                                                                               |                                                                                                                                                                                                                                        |
| <p>This enclosure is suitable for the application due to its IP Rating and is robustness. The enclosure has ventilation which will also help with airflow within the enclosure, inside the enclosure all the internal components will be mounted to the back plate, this will ensure security to minimize damage while transporting the weather station. The enclosure also comes with a gland plate at the bottom, this is where all external components cables will be connected into using panel connectors IP68.</p> |      | <p>The Rittal pole clamps is a simple method approach to mounting the enclosure, it also aids with ease of erection and dissembling of the weather station when the testing is completed.</p> | <p>This Tripod will make it easy for the user to erect mount the enclosure when using the system, the tripod 3-way legs will also aid in stabilisation to minimize the risk of the enclosure being blown over in harsh conditions.</p> |

Table 15

3.8 Panel Cooling

The following table illustrates the cooling system for the enclosure.

|                                                                                                                                                                                                                                                                                 |                 |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|
| <div></div> <p>Figure 26</p>                                                                                                                                                                  |                 |
| [47] <u>Rittal Enclosure Fan</u>                                                                                                                                                                                                                                                |                 |
| Voltage = 24 VDC                                                                                                                                                                                                                                                                | Power= 1 W/42mA |
| Dimensions = 60 X 60 X 25.4mm                                                                                                                                                                                                                                                   |                 |
| This mini fan will be used to circulate the air flow which will help provide true readings for VOC measurements while also keeping the components cool in hot environments, since the enclosure has vents, this will work well to create positive airflow throughout the panel. |                 |

Table 16

## 4. Microcontroller Specification

### 4.1 Memory Specification

The following table illustrates the memory that will be required over the 14-day measurement cycle, this will aid in choosing a suitable SD card size.

| <b>MEMORY</b>                  |                                  |                         |             |                             |                         |
|--------------------------------|----------------------------------|-------------------------|-------------|-----------------------------|-------------------------|
| <b>Sensor</b>                  | <b>Time for each measurement</b> | <b>Sample Rate (Hz)</b> | <b>Bits</b> | <b>Total Bytes</b>          | <b>Bytes Per second</b> |
| <b>UV Levels (UVA-UVB-UVC)</b> | 2Minutes=120s                    | $1/300 = 0.00833$       | 9           | 2                           | 0.01666                 |
| <b>Air borne particle</b>      | 2Minutes=120s                    | $1/300 = 0.00833$       | 10          | 2                           | 0.01666                 |
| <b>Wind Speed</b>              | 30 Seconds                       | $1/30 = 0.333$          | 7           | 1                           | 0.0333                  |
| <b>Wind Direction</b>          | 30 seconds                       | $1/30 = 0.333$          | 9           | 2                           | 0.666                   |
| <b>VOC Levels</b>              | 2Minutes=120s                    | $1/300=0.00333$         | 10          | 2                           | 0.00666                 |
| <b>Temperature</b>             | 5 Minutes=300s                   | $1/300 = 0.00333$       | 8           | 1                           | 0.00333                 |
| <b>Humidity</b>                | 5 Minutes=300s                   | $1/300 = 0.00333$       | 7           | 1                           | 0.00333                 |
| <b>GPS Position</b>            | 30 Minutes =1800s                | $1/1800 = 0.000556$     | 8           | 1                           | 0.000556                |
| <b>Sunlight Brightness</b>     | 1 Minute=60s                     | $1/60 = 0.1667$         | 9           | 2                           | 0.3334                  |
|                                |                                  |                         |             | Total Bytes Per second (B)  | 1.079896                |
|                                |                                  |                         |             | Total Bytes Per Hour (B)    | 3887.6256               |
|                                |                                  |                         |             | Total Bytes Per Day(B)      | 93303.0144              |
|                                |                                  |                         |             | Total Bytes Per 14 Days (B) | 1306242.202             |
|                                |                                  |                         |             |                             | <b>1.306MB</b>          |

Table 17

### 4.2 Retrieving Data

The following table states the SD card components and the USB interface components that have been chosen for the design.

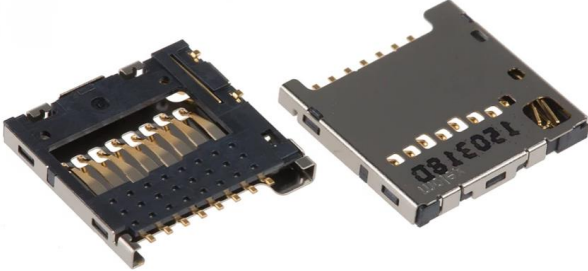
|                                                                                                    |                                                                                                                                                                                                   |                                                                                                                                                                                                                                                          |
|----------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|  <p>Figure 27</p> |  <p>Figure 28</p>                                                                                               |  <p>Figure 29</p>                                                                                                                                                     |
| <p>[48] <b><u>Molex, 104031 8 Way Push/Pull Micro SD Memory Card Connector</u></b></p>             | <p>[49] <b><u>Micro SD Card</u></b></p>                                                                                                                                                           | <p>[50] <b><u>Panel Mount Type A USB Connector</u></b></p>                                                                                                                                                                                               |
| <p>Cost = £2.166</p>                                                                               | <p>512MB      Cost =£32.10</p>                                                                                                                                                                    | <p>IP67      Cost= £6.61</p>                                                                                                                                                                                                                             |
| <p>The SD Card connector with be used to store all the data recorded for the user.</p>             | <p>This SD Card has a memory size of 512MB, this will enable the user to save a very large number of tests onto the SD Card since the total memory usage of over the 14 days is only 1.306MB.</p> | <p>This IP67 USB Panel mount connector will allow the user to access all the data from outside the enclosure, this will mitigate the risk of damage to components from rain or physical damage when trying to connect the USB cable to collect data.</p> |

Table 18

### 4.3 Total Pin Count

| <b><u>PIN Count</u></b>                  |                           |                             |                               |                          |                           |
|------------------------------------------|---------------------------|-----------------------------|-------------------------------|--------------------------|---------------------------|
| <b><u>Parameter for Measurement</u></b>  | <b><u>Output Type</u></b> | <b><u>Output Signal</u></b> | <b><u>Total Pin Count</u></b> | <b><u>Pins to MC</u></b> | <b><u>Application</u></b> |
| <b><u>UV Levels (UVA-UVB-UVC)</u></b>    | Analogue                  | 4-20mA                      | 3                             | 1                        | Sensor                    |
| <b><u>Air borne particle</u></b>         | Analogue                  | 4-20mA                      | 3                             | 1                        | Sensor                    |
| <b><u>Wind Speed &amp; Direction</u></b> | Analogue                  | 4-20mA                      | 4                             | 2                        | Sensor                    |
| <b><u>VOC Levels</u></b>                 | Digital                   | I2C                         | 6                             | 2                        | Sensor                    |
| <b><u>Temperature &amp; Humidity</u></b> | Digital                   | RS485                       | 6                             | 2                        | Sensor                    |
| <b><u>GPS Position</u></b>               | Digital                   | UART                        | 3                             | 2                        | Sensor                    |
| <b><u>Sunlight Brightness</u></b>        | Analogue                  | 4-20mA                      | 5                             | 1                        | Sensor                    |
| <b><u>USB</u></b>                        | Digital                   | I2C                         | 4                             | 2                        | Data Read                 |
| <b><u>SD Card</u></b>                    | Digital                   | I2C                         | 4                             | 4                        | Data Read                 |
| <b><u>Start Button</u></b>               | -                         | -                           | 2                             | 1                        | Start Test                |
| <b><u>Supply</u></b>                     | -                         | -                           | 2                             | 1                        | -                         |
| <b><u>GND</u></b>                        | -                         | -                           | GND                           | 1                        | GND                       |
| <b><u>LED</u></b>                        | -                         | -                           | 4                             | 1                        | Indication                |
|                                          |                           |                             |                               |                          |                           |

Table 19

The total pin count for all components connecting to the micro controller is 21 pins. The closest standard pin counts on micro controllers are 28 and 40, understanding this the most suitable pin size for this system would be the 28-pin package, this will then allow for expansion for future reference.

#### 4.4 Microcontroller Selection

To select the most suitable microcontroller a specification will need to be met using all the below criteria in the table that compares the microcontrollers specification to the specification for this system.

- 28 Pins
- USB Compatible
- 10-Bit ADC Resolution
- I2C
- Internal Oscillator
- Operation Voltage – 3.3 VDC
- 8MHz Oscillator
- UART

The choice was made using the microchip website tool, this offered a four-microchip comparison to help decide on the best suited microchip for the design, the chip that was most suitable was the PIC18F2550. This PIC offered a bigger specification that was needed while meeting the criteria that was set from the design.

| Parametrics                             |                        |
|-----------------------------------------|------------------------|
| Program Memory Size (KB)                | 32                     |
| RAM (bytes)                             | 2048                   |
| Data EEPROM (bytes)                     | 256                    |
| Pin Count                               | 28                     |
| Operation Voltage Max.(V)               | 5.5                    |
| Operation Voltage Min.(V)               | 2                      |
| Timers                                  | 1 x 8-bit - 3 x 16-bit |
| Max ADC Resolution (bits)               | 10                     |
| ADC Channels                            | 10                     |
| Zero Cross Detect                       | No                     |
| Number of Comparators                   | 2                      |
| SPI                                     | 1 -SPI                 |
| I2C                                     | 1 -I2C                 |
| Stand alone PWM                         | 0                      |
| Low Power                               | No                     |
| Numerically Controlled Oscillator (NCO) | 0                      |
| Data Signal Modulator (DSM)             | 0                      |

Figure 31

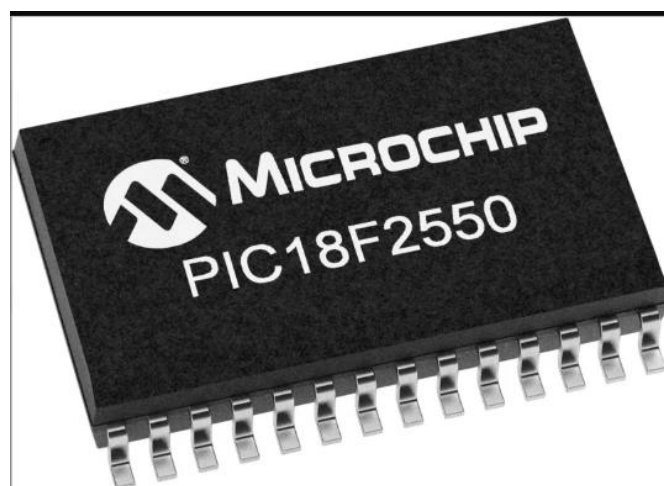


Figure 30

## 5. System Design

### 5.1 Schematic Design

The figure below illustrates the full schematic design of the 14-day weather monitoring system, the schematic design was completed on Easy PC software.

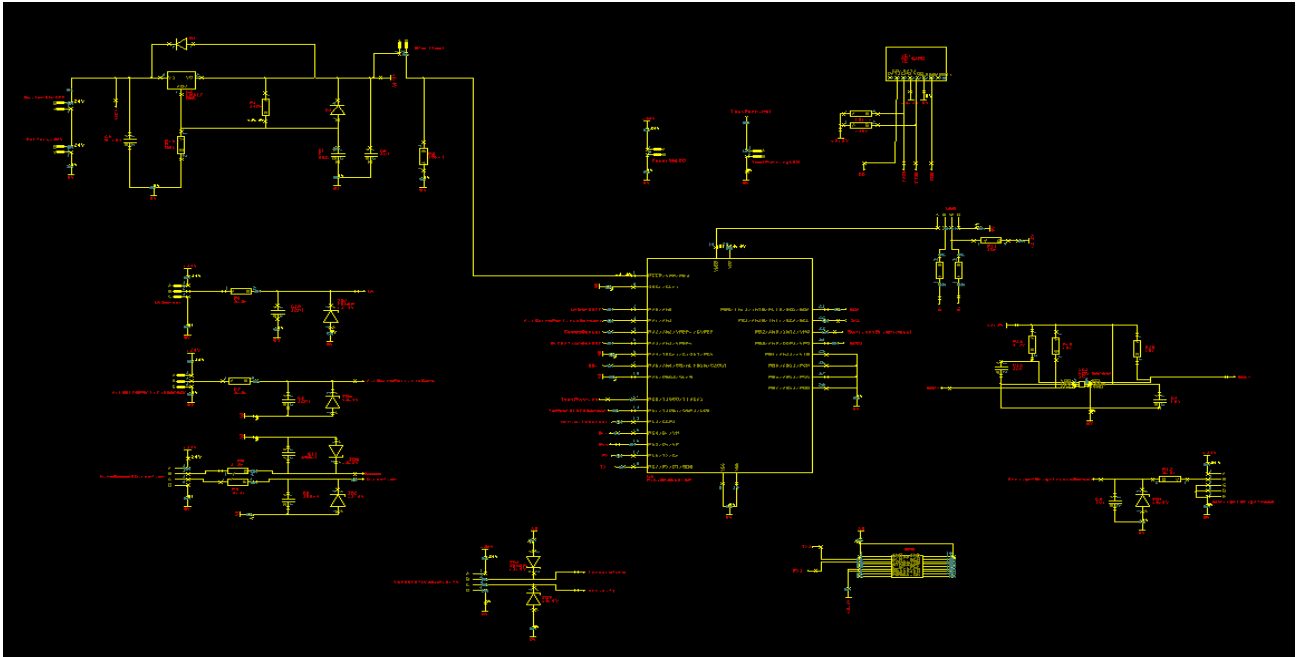


Figure 32

The figure below demonstrates the supply circuit, this circuit ranges from a 24VDC supply, this will supply the 24VDC components, the 24VDC then terminates into a LM317 adjustable regulator which will regulate the voltage to +3.3VDC to supply the microcontroller, GPS and the VOC Level Sensor. The data sheet [51] states that R15 and R1 are required to set the output voltage, C5 is for ripple rejection, which will allow a steady supply into the components, capacitor C6 is used to improve the transient response. The diode D1 & D2 are used to give a low-impedance discharge path to stop the capacitors C1 & C6 from discharging into the output of the regulator.

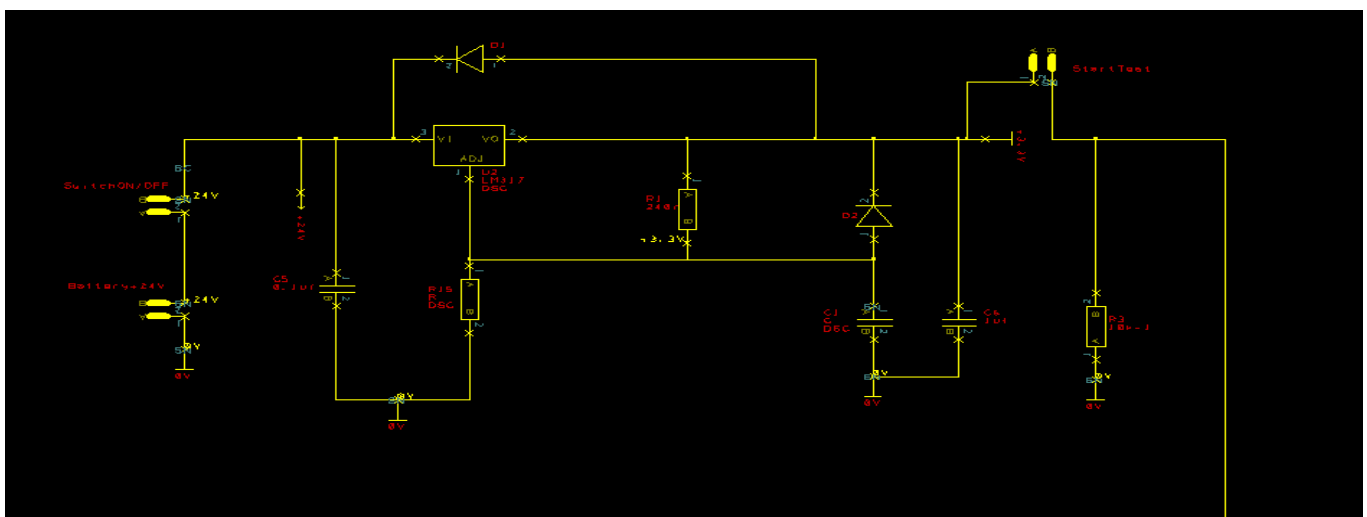


Figure 33

The figure below demonstrates the UV sensor circuitry, it consists of a 24VDC supply, GND and a 4-20mA output signal. The output signal has a low pass filter and overvoltage protection, the low pass filter consists of a resistor and capacitor (RC) this will attenuate any unwanted high frequencies that could be induced onto the circuit. The overvoltage protection consists of a 3.4V Zener diode, if a transient voltage is induced onto the signal that exceeds 3.4V then the Zener will become conductive and take the voltage to ground, resulting in the microcontroller and other components not being damaged. The same application of filtering and overvoltage protection will apply to the air borne particle circuit, the wind speed and direction circuit, and the sunlight brightness circuit as they are all analogue signals which produce a 4-20mA output.

The following calculation is to calculate the capacitance value for the low pass filter, firstly a suitable resistor size will need to be chosen, this will be 3.3k $\Omega$  resistor since they are a common size and reasonable. The frequency cut off will need to be calculated, this is applied by dividing the sample rate by 2. The UV level sample rate is 0.00833 Hz which will result in the frequency cut of being 0.00417Hz.

$$F_c = \frac{1}{2\pi RC}$$

$$C = \frac{1}{2\pi R F_c}$$

$$C = \frac{1}{2\pi \times 3300 \times 0.00417}$$

$$C = 0.012f$$

The closest capacitor to this size is a 12000uF capacitor [52].

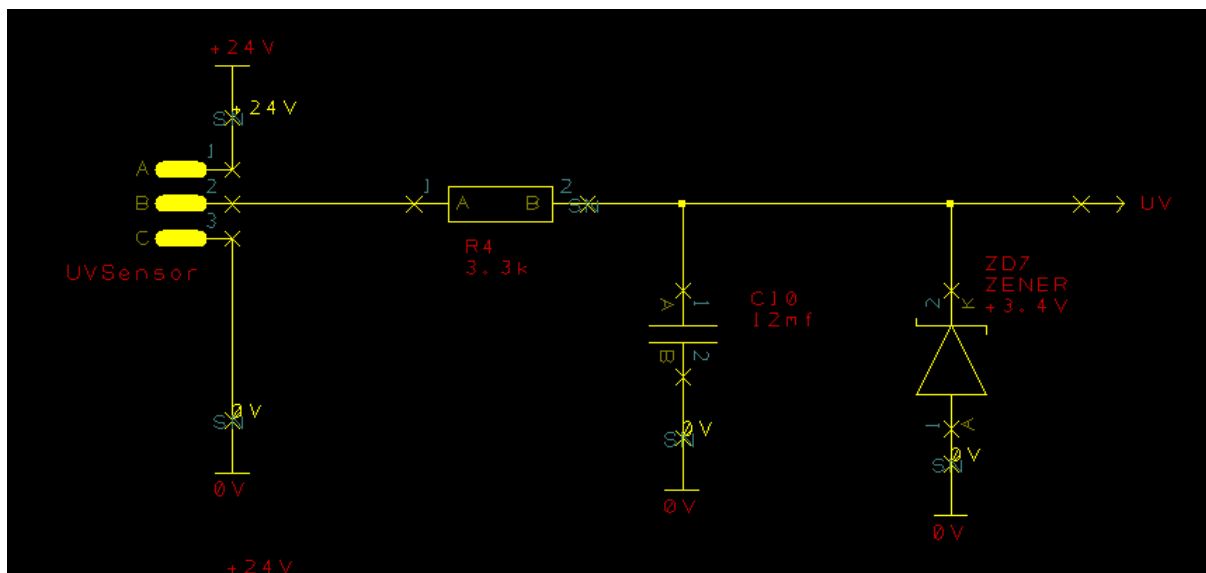


Figure 34

The below figure illustrates the Airborne particle sensor circuitry, the circuitry and values are the same as the UV level sensor since it is a three-pin analogue, 4-20mA output signal and the sample rate is also 0.00833Hz.

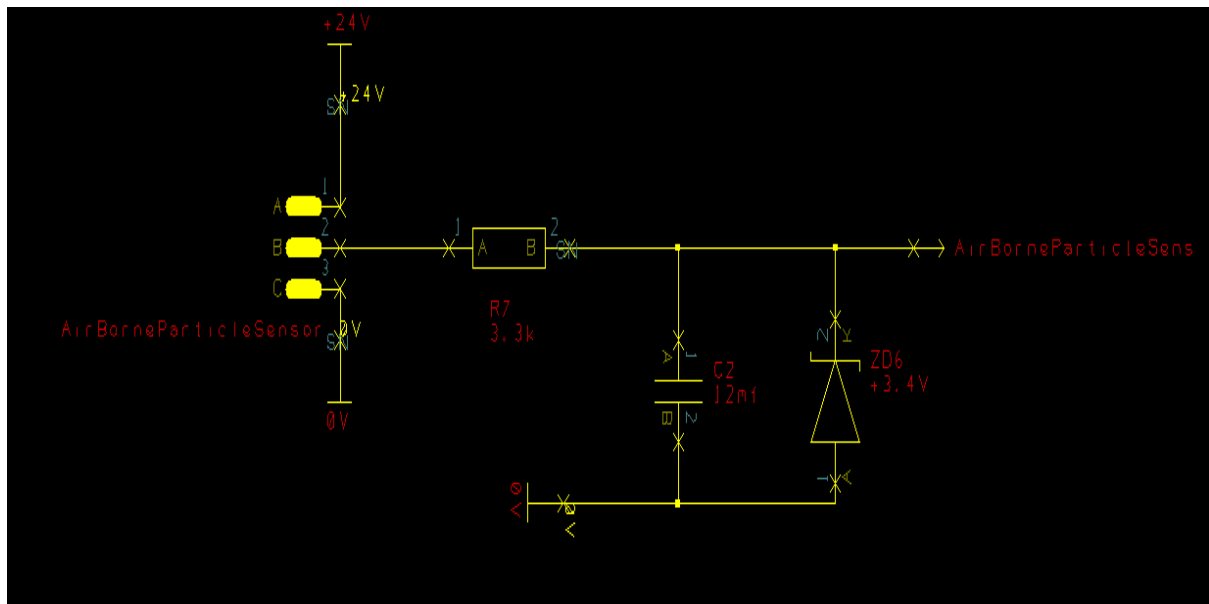


Figure 35

The figure below represents the wind speed and direction sensor, this consists of a 24VDC supply a ground and two 4-20mA output signals, the circuitry is the same as the UV level sensor and the air borne particle sensor. The calculation for the low pass filter has changed since the sample rate is 0.333Hz which results in the frequency cut off being 0.1665Hz, the calculation follows below.

$$F_c = \frac{1}{2\pi RC}$$

$$C = \frac{1}{2\pi R F_c}$$

$$C = \frac{1}{2\pi \times 3300 \times 0.1665}$$

$$C = 0.00029f$$

The closest capacitor to this size is a 290uF capacitor [53].

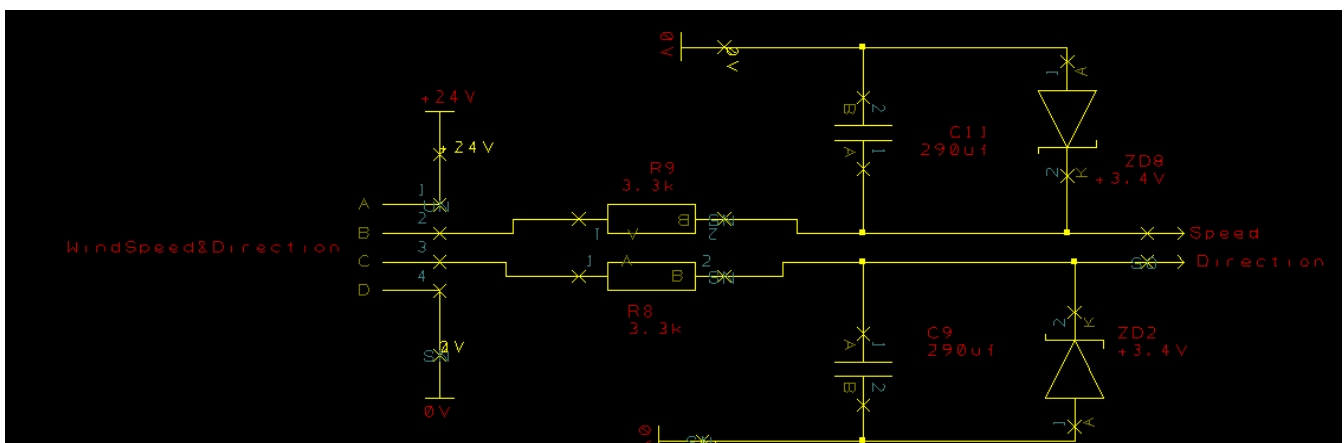


Figure 36

The following figure represents the temperature and humidity sensor circuitry, this sensor has a supply of 24VDC with a ground, the two output signals also have overvoltage protection which consists of a +3.4V Zener diode which will protect the circuit by becoming conductive in the event of transient voltages onto the output signal.

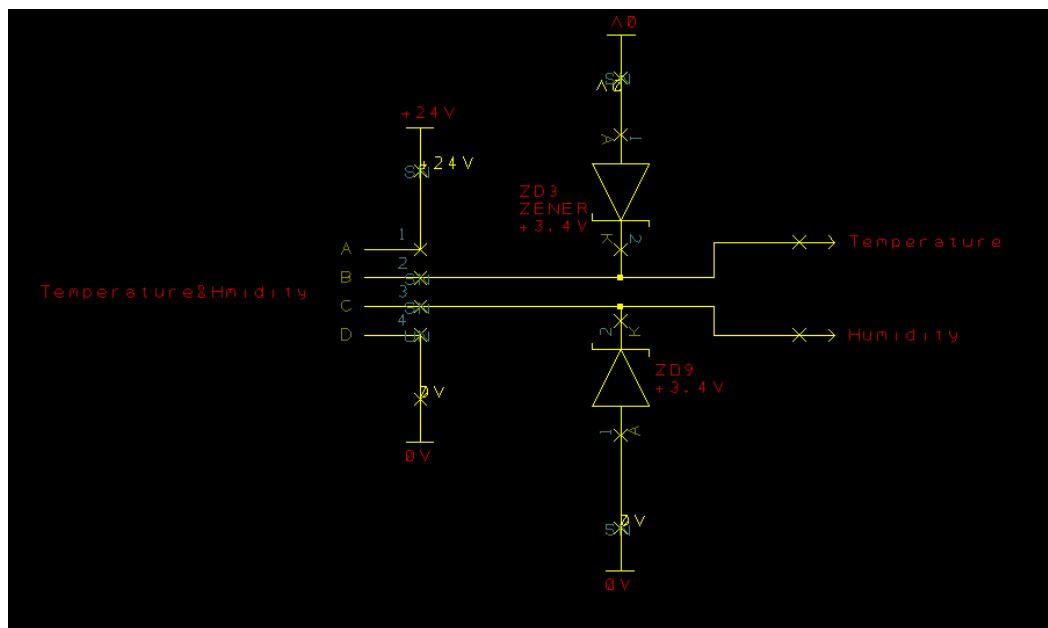


Figure 37

The figure below demonstrates the GPS circuitry, which has UART communication interface, this consist of a +3.3VDC supply, a ground and a transmit and receive to the micro controller.

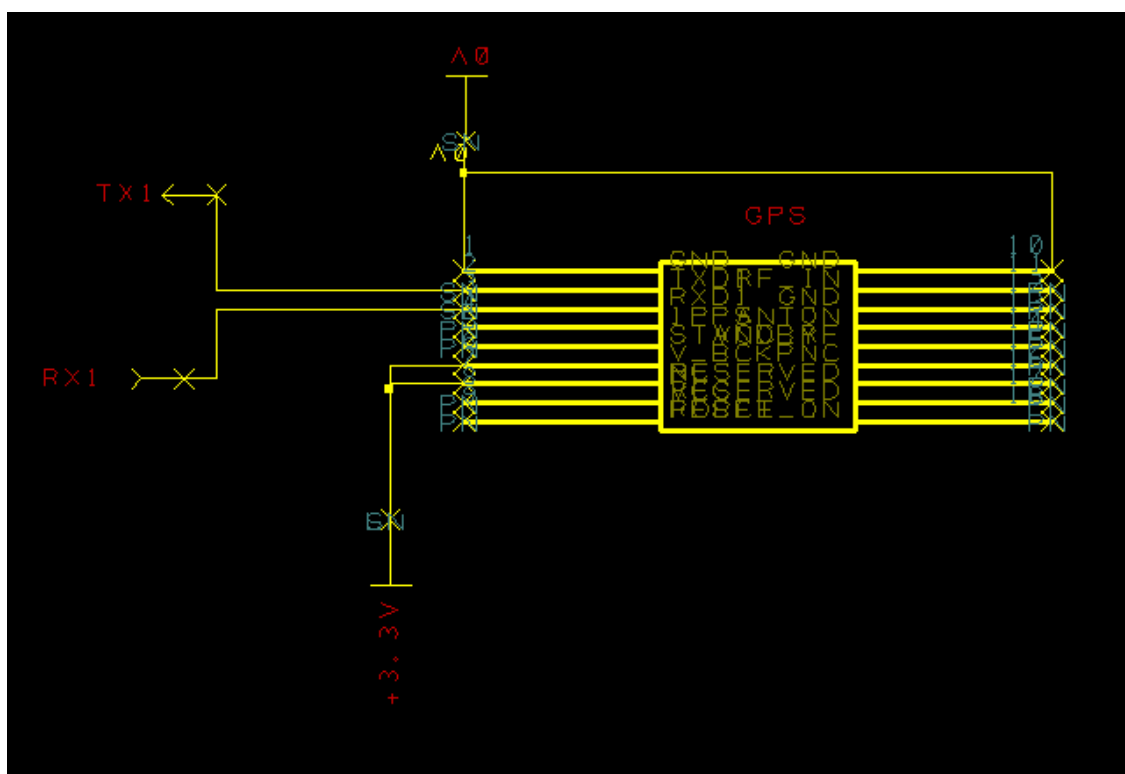


Figure 38

The following figure represents the sunlight brightness sensor, this sensor has a +24VDC supply and ground, the output signal is an analogue signal which will also need a low pass filter and overvoltage protection, the sample rate is 0.1667Hz which results in the frequency cut off being 0.08335Hz. The following calculation is to find the capacitor value.

$$F_c = \frac{1}{2\pi RC}$$

$$C = \frac{1}{2\pi R F_c}$$

$$C = \frac{1}{2\pi \times 3300 \times 0.08335}$$

$$C = 0.00058f$$

The closest capacitor to this size is a 580uF capacitor [54].

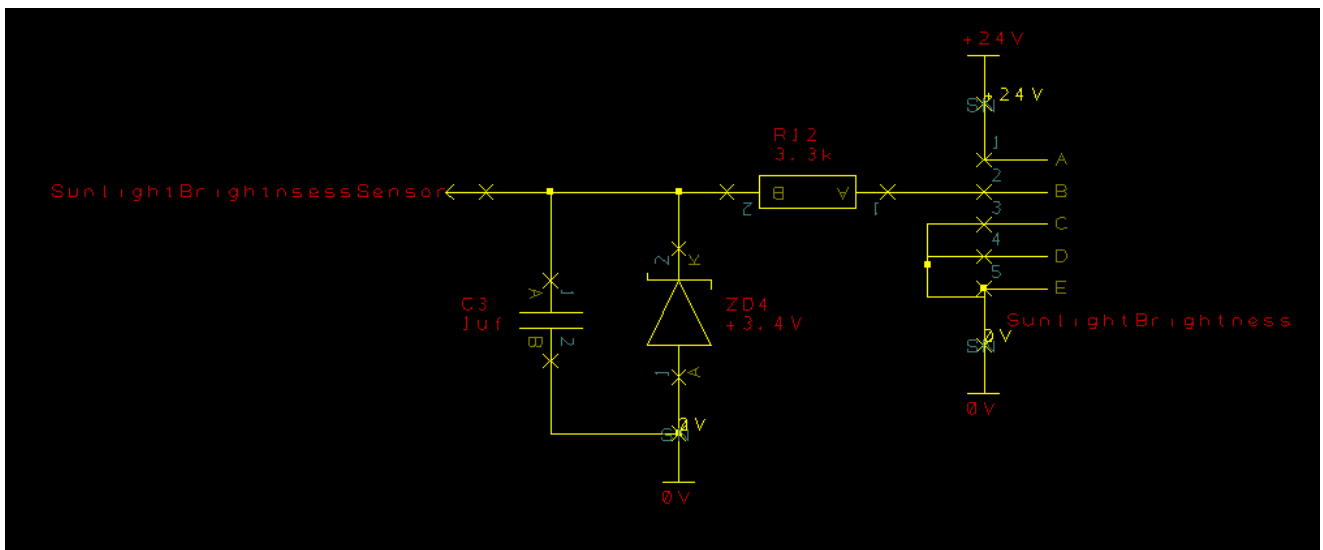


Figure 39

The figure below illustrates the VOC sensor, the supply voltage is +3.3VDC, ground and the output signal is I2C communication interface. The SDA and SCL have pull up resistors, this ensures the SDA and SCL lines are in a high state when no data is sending which can then allow other devices to send data on the same bus.

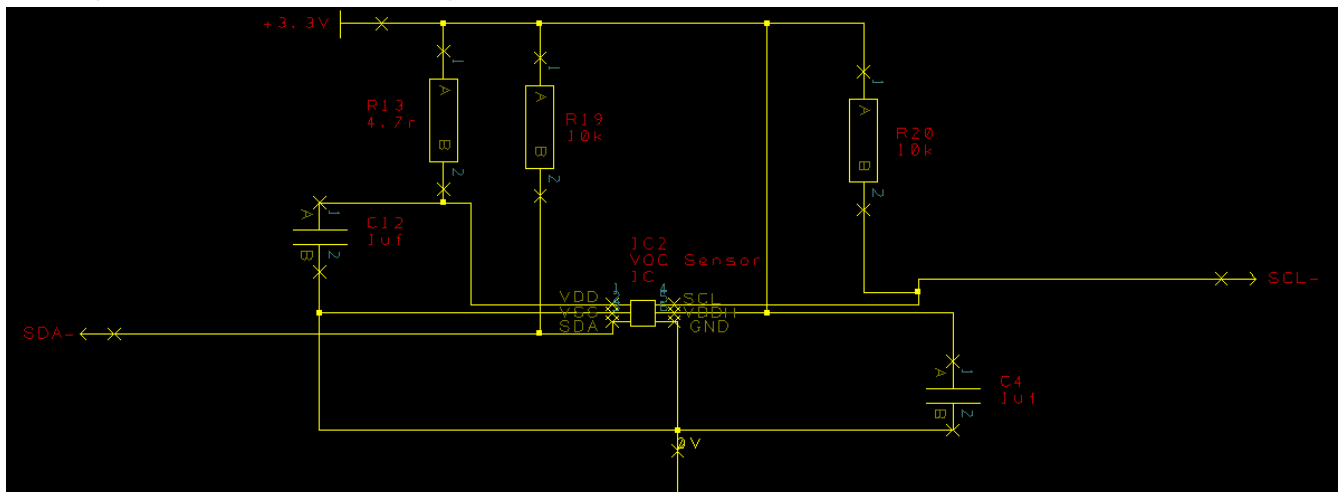


Figure 40

The following figure shows the circuitry for the SD card interface, this also uses I2C interface which will also result in the SDA and SCL lines needing pull-up resistors.

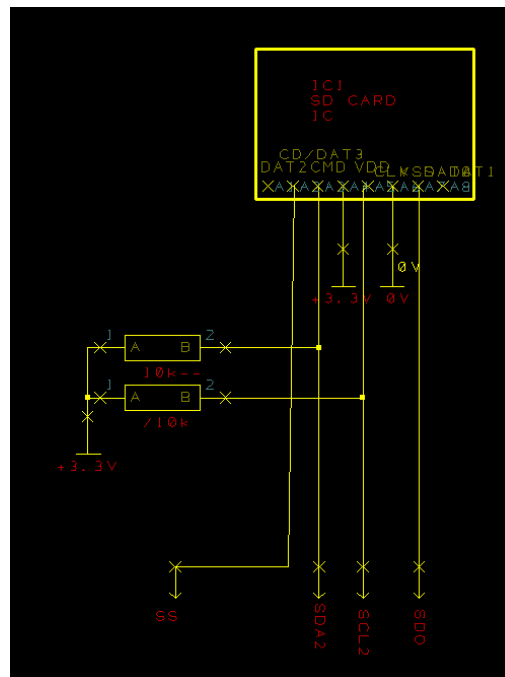


Figure 41

The figure below demonstrates the USB circuitry the input signal is supplied via the PIC +3.3V while the output signal is a half-duplex protocol, this contains two data lines of D+ & D- with a pull up resistor on the D+.

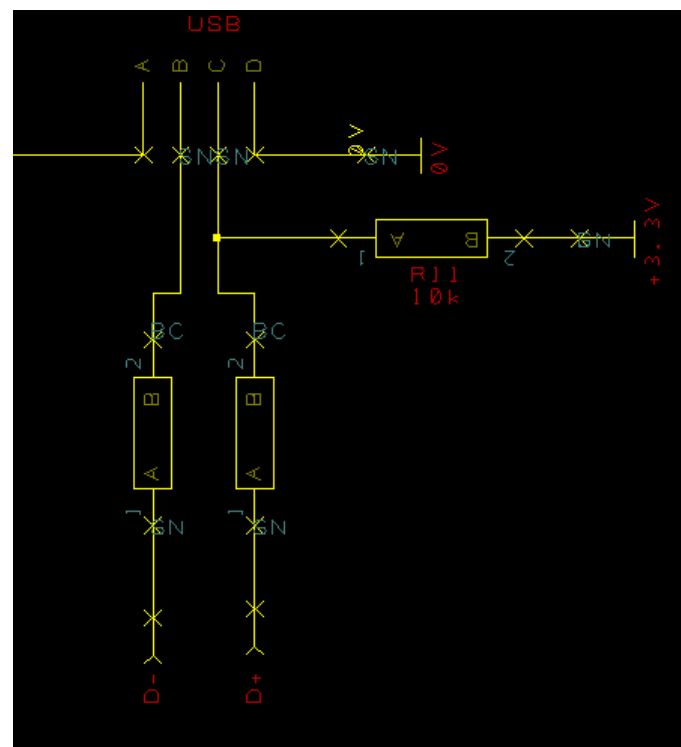


Figure 42

The circuitry for the LEDs is shown in the figure below, the panel mount 'Power ON LED' is to indicate to the user that the power has been switched on. The 'test running LED' will illuminate when the panel mount start button has been pressed and the test has started running, this will be a +3.3V LED which will be supplied by the microcontroller.

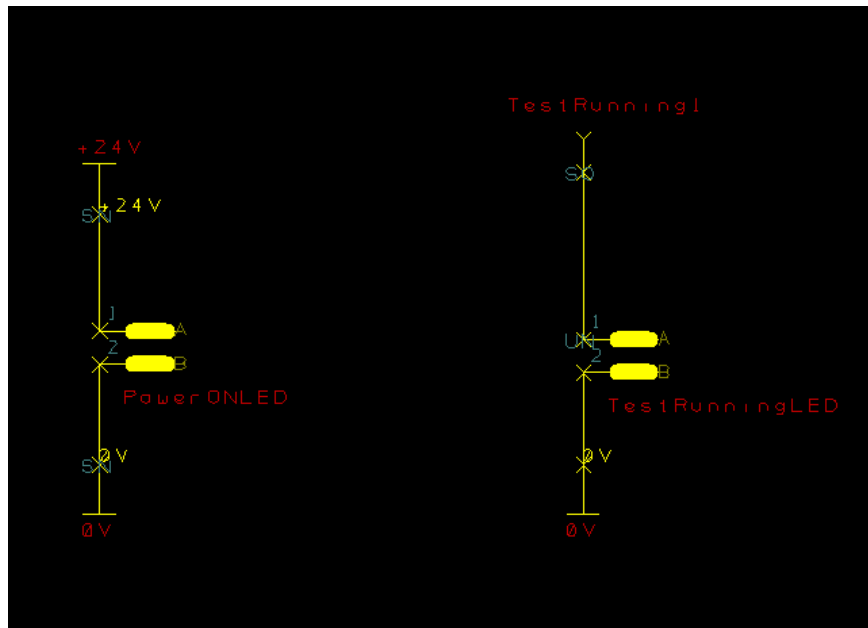


Figure 43

The below figure illustrates the PIC with all the inputs and outputs.

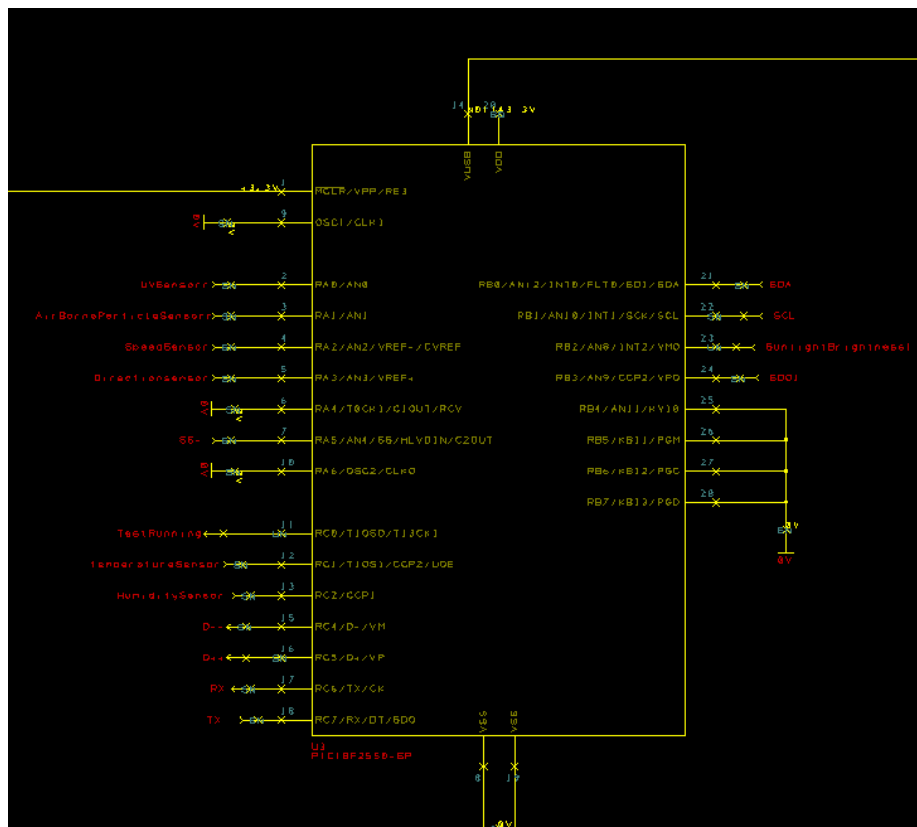


Figure 44

## 5.2 PCB Design

The figure below demonstrates the PCB design prior to a copper pour, the PCB also has mounting holes in the corners which will help the mounting of the PCB to ensure it is secure so no damage can occur.

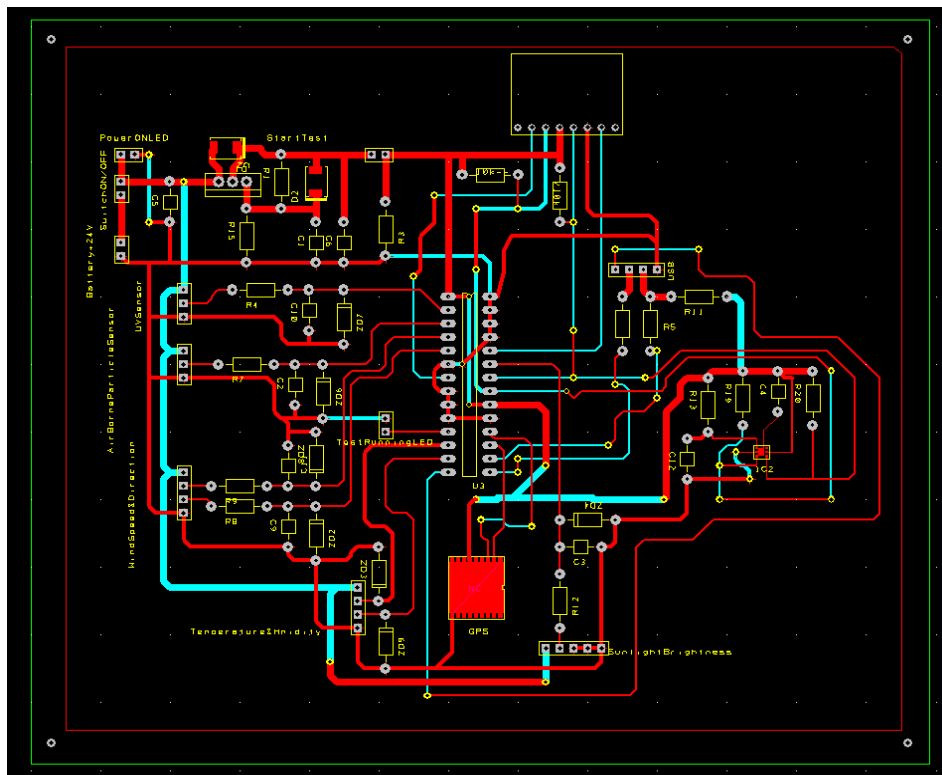


Figure 45

The below figure illustrates the PCB with the copper poured through the 0V net.

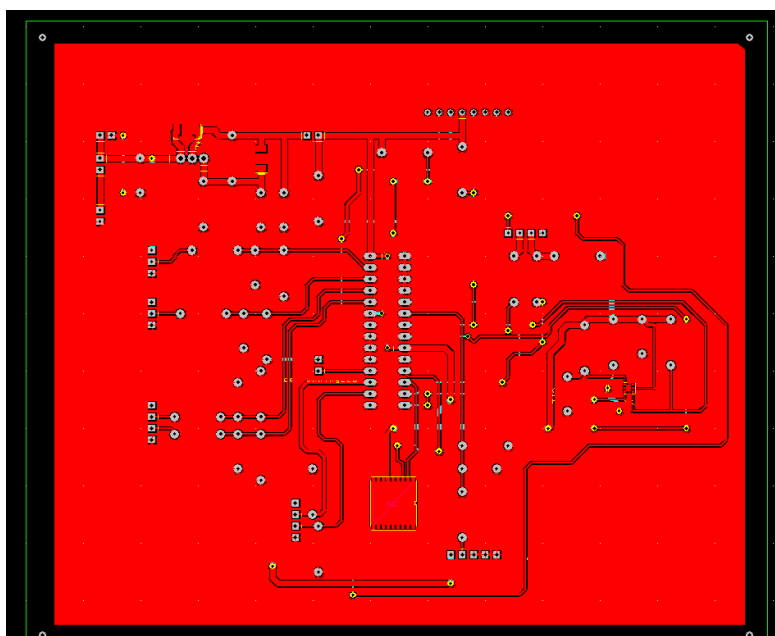


Figure 46

The figure below illustrates the PCB 3D view when the copper has been poured.

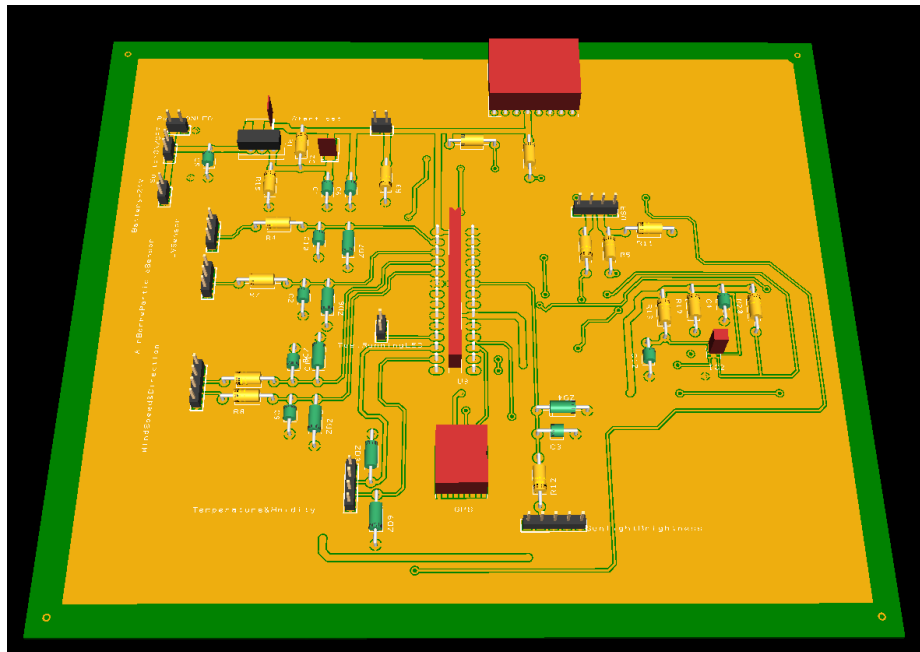


Figure 47

The figure below demonstrates the PCB 3D model.

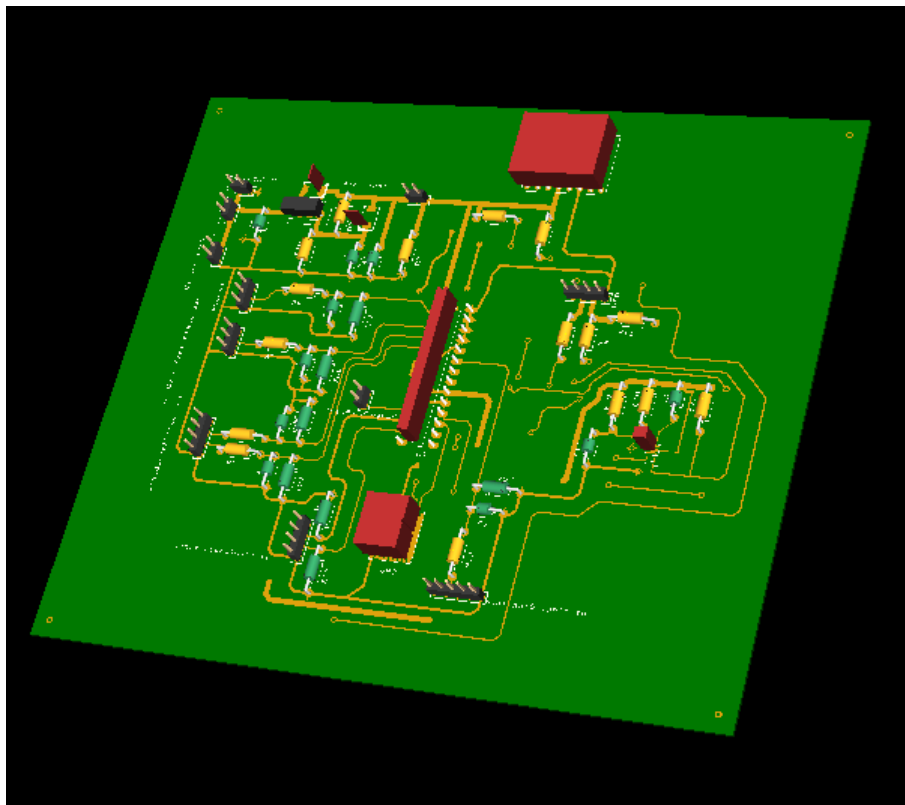


Figure 48

The figure below illustrates the bottom layer of the PCB 3D model.

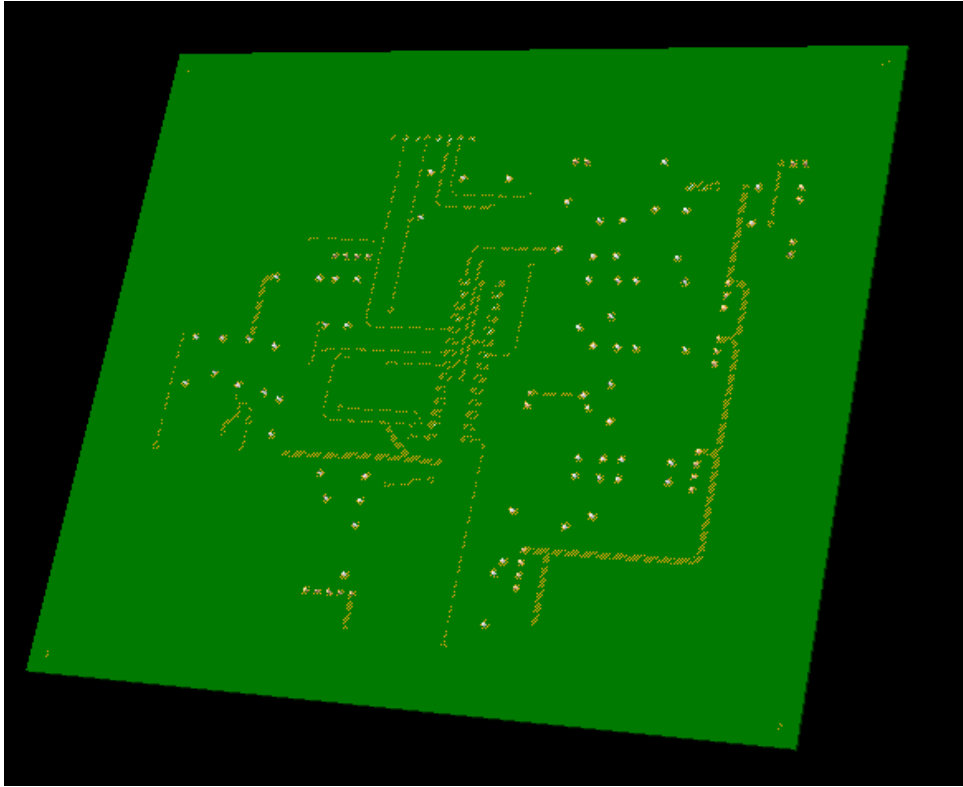


Figure 49

6. Structure Diagram

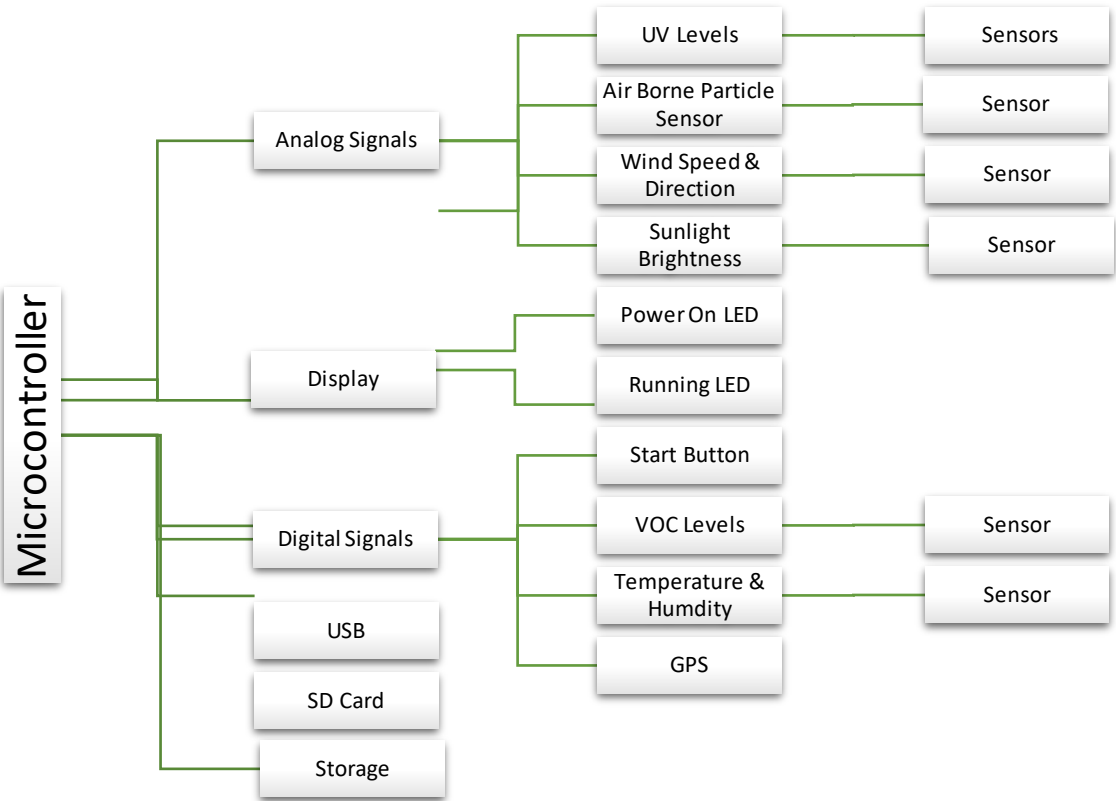


Figure 50

7. Estimated Build Cost

The below figure illustrates the cost for manufacturing of the PCB.

Standard PCB/PCBA

Advanced PCB/PCBA

SMT-Stencil

3D/CNC

Back to Upload File

Detected 2 layer board of 139.7x163.83mm(5.5x6.45 inches)

Gerber Viewer

Base Material

FR-4FlexAluminumCopper CoreRogersPTFE Teflon

Layers

124High Precision PCB68101214161820

Dimensions

163.83 \* 139.7mm

PCB Qty

5

Product Type

Industrial/Consumer electronicsAerospaceMedical

PCB Specifications

Different Design

1234

Delivery Format

Single PCBPanel by CustomerPanel by JLCPCB

PCB Thickness

0.40.60.81.01.21.62.0

PCB Color

GreenPurpleRedYellowBlueWhiteBlack

Charge Details

Engineering fee

\$4.00

Via Covering

\$0.00

Surface Finish

\$0.00

Board

\$8.70

Build Time

PCB: 3-4 days\$0.002 days\$0.0024 hours\$7.2024 hoursPCBA Only\$0.00

Calculated Price

Additional charges may apply for special cases

\$12.70

SAVE TO CART

Shipping Estimate

Charge: Choose destination country first

Weight0.51kg

Figure 51

Table 20

| <b><u>Component</u></b>                         | <b><u>Total No.</u></b> | <b><u>Unit Price (£)</u></b> | <b><u>Total Price (£)</u></b> |
|-------------------------------------------------|-------------------------|------------------------------|-------------------------------|
| <b><u>UV Sensor</u></b>                         | 1                       | £236.44                      | 236.44                        |
| <b><u>Sunlight Brightness Sensor</u></b>        | 1                       | £298                         | £298                          |
| <b><u>Temp &amp; Humidity Sensor</u></b>        | 1                       | 168                          | 168                           |
| <b><u>Wind Speed &amp; Direction Sensor</u></b> | 1                       | 148                          | 148                           |
| <b><u>Air Bourne Particle Count Sensor</u></b>  | 1                       | 610.8                        | 610.8                         |
| <b><u>VOC Level Sensor</u></b>                  | 1                       | 8.64                         | 8.64                          |
| <b><u>GPS Position Sensor</u></b>               | 1                       | 9.439                        | 9.439                         |
| <b><u>3 pin panel mount connector</u></b>       | 2                       | 7.88                         | 15.76                         |
| <b><u>3 pin cable connector</u></b>             | 2                       | 7.88                         | 15.76                         |
| <b><u>4 pin panel mount connector</u></b>       | 2                       | 12.43                        | 24.86                         |
| <b><u>4 pin cable connector</u></b>             | 2                       | 12.43                        | 24.86                         |
| <b><u>5 pin panel mount connector</u></b>       | 1                       | 23                           | 23                            |
| <b><u>5 pin cable connector</u></b>             | 1                       | 20.04                        | 20.04                         |
| <b><u>Molex board Connectors</u></b>            | 1 Pack                  | 8.81                         | 8.81                          |
| <b><u>On/Off keyy switch</u></b>                | 1                       | 19.4                         | 19.4                          |
| <b><u>start button</u></b>                      | 1                       | 3.35                         | 3.35                          |
| <b><u>LEDs</u></b>                              | 2                       | 2.88                         | 5.76                          |
| <b><u>Battery</u></b>                           | 1                       | 619.99                       | 619.99                        |
| <b><u>Enclosure</u></b>                         | 1                       | 620                          | 620                           |
| <b><u>Rittal Pole Clamp</u></b>                 | 1 Pack                  | 71.28                        | 71.28                         |
| <b><u>Tripod</u></b>                            | 1                       | 156.14                       | 156.14                        |
| <b><u>Enclosure Fan</u></b>                     | 1                       | 33.67                        | 33.67                         |
| <b><u>SD card Connector</u></b>                 | 1                       | 2.166                        | 2.166                         |
| <b><u>SD card</u></b>                           | 1                       | 32.1                         | 32.1                          |
| <b><u>Panel Mount USB</u></b>                   | 1                       | 6.61                         | 6.61                          |
| <b><u>Microcontroller</u></b>                   | 1                       | 7.86                         | 7.86                          |
| <b><u>PCB Manufacture</u></b>                   | 1                       | 9.96                         | 9.96                          |
| <b><u>Total Cost = (£)</u></b>                  |                         |                              | 3200.695                      |

Table 21

## 8. Reflection for Improvements

This section covers the reflection of the design pointing out any improvements that could be made. The background research provided information on the existing systems that had more capabilities, such as wirelessly viewing real time data, this could make the system more attractive since the user could see the data from an indoor environment instead of being outside in possibly bad conditions.

The next improvement that could be used is the temperature, humidity and air borne particle sensor being in one module, this could save on the overall cost of the design while making it easier for installation.

The next beneficial improvement to the design could be adding a small solar panel onto the enclosure which would allow the battery to recharge resulting in a more efficient power system. Regarding battery capability the batter usage could have been calculated more efficiently by calculating the standby power usage of each component, this would then ensure that the power consumption is minimised causing the overall cost to be reduced and the battery size would also be reduced.

The cost of the system could be reduced also by choosing cheaper sensor options, the only negative point with this is that it may decrease the accuracy of the measurements if cheaper sensors are used or, be more liable to breaking components.

To conclude the report the project has been successful as all the criteria was met, if this project was to be revised or repeated the improvements above would be considered.

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