

Electronic System Design Assignment Two



Level 6 Assignment

Submitted By

Gareth Davies (2218705)

Abstract

This report aims to develop a compact weather station to monitor and record meteorological data. The design incorporates various sensors and instruments to measure temperature, humidity, wind, sunlight, and particle matter within a localised environment.

This paper will highlight how each section of the design process was undertaken from initial design research through to component selection, PCB design and enclosure development.

Contents

Abstract	2
Table of Figures	5
Introduction	6
Project Research.....	7
1. Sainlogic WS3500 [1]	7
2. Ecowitt HP2564 WittBoy Pro [4]	8
3. Netatmo Weather Station [7]	9
Component Selection	12
Wind Speed and Direction:	12
Temperature and Humidity:	13
Airborne Particle Count and VOC Levels:.....	14
Brightness:.....	14
UV:.....	15
GPS:	16
Battery:	17
USB:	18
Memory Requirements	20
SD Card:	23
.....	23
Microcontroller Selection	24
.....	25
Connector Selection	26
Circuit Design	28
Power Distribution:.....	28
Sensor Signal Conditioning:	28
LED:.....	29
Circuit Schematic:.....	29
PCB Design:	33
PCB 3D Model:	34
PCB Cost:.....	34
Enclosure	35
Project Costing	37

Software Structure.....	39
1. Mode Selection:.....	39
2. Data Upload Mode:	40
3. Data Acquisition Mode:.....	41
Design Improvements	42
1. Battery Sustainability:	42
2. Sample Rate:.....	42
3. VOC Alarm:	42
Conclusion	43

Table of Figures

Figure 1 - Sainlogic WS3500.....	7
Figure 2 - Transducer Configuration to Measure Wind Speed and Direction	8
Figure 3 - Ecowitt HP2564 WittBoy Pro.....	9
Figure 4 - Netatmo Weather Station.....	10
Figure 5 - WindSonic 60 Anemometer	12
Figure 6 - Sensirion SHT3x-DIS.....	13
Figure 7 - Sensirion SPS30 PM10 Particle Sensor	14
Figure 8 - NORPS-12 LDR Photoresistor.....	15
Figure 9 - Optoelectronics UV-035DQC Photodiode.....	15
Figure 10 - ATGM336H-5N GPS Module	16
Figure 11 - Ansmann 14.54V Li-Ion Re-Chargeable Battery	18
Figure 12 - Amphenol Typer B USB Connector	19
Figure 13 - Moles Micro-SD Card Connector and Kingston Mirco-SD Card	23
Figure 14 - Microcontroller Comparison	25
Figure 15 - 7805 Voltage Regulator Configuration	28
Figure 16 – 50Hz LPF with 5V Overvoltage Protection	29
Figure 17 - Schematic of Microcontroller Connections.....	29
Figure 18 - Schematic of PM & VOC and Wind Speed & Direction Sensors.....	30
Figure 19 - Schematic of GPS Connection to Microcontroller	30
Figure 20 - Schematic of UC and Brightness Sensor Connections	31
Figure 21 - Schematic of Temperature & Humidity Sensor Connections	31
Figure 22 - Schematic of USB and SD Card Holder Connections.....	32
Figure 23 - Schematic of 7805 Voltage Regulator Connections.....	32
Figure 24 – Project PCB Design	33
Figure 25 - 3D Model of PCB Design	34
Figure 26 - JLCPCB PCB Quote	34
Figure 27 - Basic Design Concept.....	35
Figure 28 - Software Structure for Mode Selection	39
Figure 29 - Software Structure for Data Upload	40
Figure 30 - Software Structure for Data Acquisition	41

Introduction

Weather stations are essential tools used to collect and measure various atmospheric conditions such as temperature, humidity, precipitation, and wind. These stations utilise a variety of sensors to gather accurate weather data in real-time. They are deployed across the globe and offer valuable information to meteorologists, researchers, and even everyday individuals to predict weather patterns.

For this project, it has been requested that a weather station be designed for hobbyist applications. Using basic electronic components and carefully selected sensory equipment, this report will show just how one such device can be designed.

Project Research

Different weather stations are designed utilising a wide range of sensors that can measure the same parameter. Depending on applications, each type of sensor has its pros and cons. To determine which sensors will be best for this project, initial market research was conducted.

1. Sainlogic WS3500 [1]

The Sainlogic WS3500 is a traditionally designed weather station that uses a cup anemometer to measure wind speed and wind vane to gauge its direction. Optical sensors are used to obtain input data from both of these applications.

It also processes a four-inch rain gauge that funnels rainfall into a tipping bucket mechanism. This acts as a “seesaw” and uses the weight of water gathered to unbalance the mechanism and operate a switch. Once switched, the water gathers on the opposite side of the scale and triggers the switch again [2]. By calibrating the weight at which this occurs, rainfall over a period of time can be calculated.

The datasheet for this product specifies that it also measures temperature and UV levels, although doesn't state how it detects these conditions.



Figure 1 - Sainlogic WS3500

2. Ecowitt HP2564 WittBoy Pro [4]

The Ecowitt DP2564 WittBoy Pro is a compactly designed weather station that utilises ultrasonic transducers to determine wind direction and speed.

As soundwaves travel through air, pressure changes, due to wind, will cause the soundwaves to travel at varying speeds. By measuring the time taken for an ultrasonic wave to travel over a known distance, wind speed can be determined [4].

If multiple ultrasonic transducers are configured in a compass formation as shown in Figure 2, the difference between transducer measurements will be proportional not only to wind speed, but also its velocity.

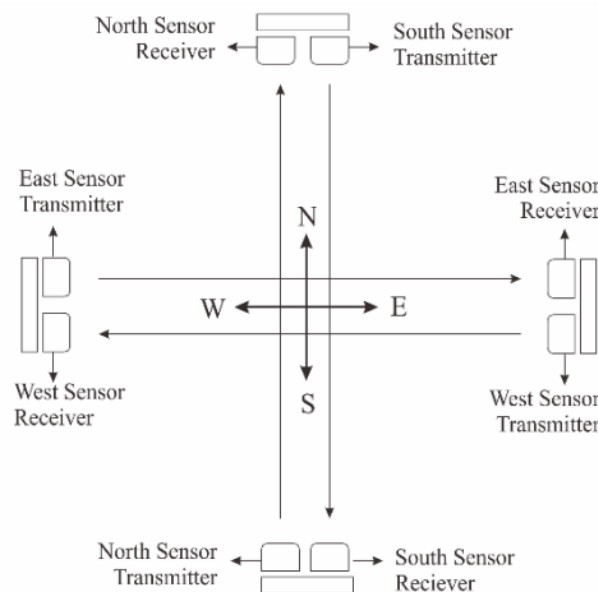


Figure 2 - Transducer Configuration to Measure Wind Speed and Direction

To measure rainfall, this product used a piezoelectric sensor. At a fundamental level, piezoelectric sensors simply convert pressure, or strain, to a proportional output voltage [5]. With a calibrated measurement area and a table of predetermined pressure values, software can be used to convert the weight of rain detected over a period of time to an equivalent rainfall value.

The datasheet for this product also states that it measures UV levels using a photodiode circuit. Depending on the intensity of sunlight, these sensors will self-induce a proportional output voltage. To maximise accuracy of this sensor, it is mounted directly on top of the station.



Figure 3 - Ecowitt HP2564 WittBoy Pro

3. Netatmo Weather Station [7]

The Netatmo Weather Station again uses ultrasonic transducers to monitor wind velocity. This ultrasonic design significantly reduces the size of weather stations when compared to the traditional cup anemometers set-up.

This product does not measure rainfall, although does measure humidity levels between a scale of 0-100%. The datasheet for this product states that capacitive sensors are used for this process.

Also known as capacitive hygrometers, these sensors detect moisture in a hygroscopic material sandwiched between two metallic plates. This material absorbs moisture rapidly and changes the capacitance between the two plates when it does so. The capacitance measured is directly proportional to the humidity level and thus, a humidity percentage can be calculated [8].

Whilst also having the ability to measure temperature, this product does not measure UV levels or rainfall. Instead, it provides the option to measure atmospheric pressure through a digital barometer, environmental sound through a decibel meter, and carbon dioxide levels via an undisclosed method.



Figure 4 - Netatmo Weather Station

For the three weather stations researched, a comparison table has been created highlighting their individual specifications as shown in Table 1.

<u>Feature</u>	<u>Sainlogic WS3500</u>		<u>Ecowitt DP2564 WittBoy Pro</u>		<u>Netatmo Weather Station</u>	
Wind Speed Sensor	✓	0 – 50m/s	✓	0 – 40m/s	✓	0 – 45m/s
Wind Direction Sensor	✓	0 – 359°	✓	0 – 359°	✓	0 – 359°
Temperature Sensor	✓	-40 – 60°C	✓	-40 – 60°C	✓	-20 – 50°C
Humidity Sensor	✗		✓	1 – 99%	✓	0 – 100%
Particle Matter Sensor	✗		✗		✓	C02 Only
Brightness Sensor	✓	0 – 200Klux	✓	0 – 200Klux	✗	
UV Sensor	✗		✓	UVI: 1 -15	✗	
Battery	✓	x3 AAA	✓	x2 AA	✓	x4 AA
Data Upload	✓	LED Display	✓	LED Display	✓	Mobile Application

Table 1 - Weather Station Research Comparison

Component Selection

Wind Speed and Direction:

A lot of modern weather stations are utilising ultrasonic over traditional cup anemometers. This is due to their compact design and multifunctional applications. Whilst a cup anemometer will only measure wind speed, a smaller ultrasonic device can also be used to monitor wind direction.

Whilst a relatively cheap ultrasonic anemometer can be designed from base components, for this project a WindSonic 60 Anemometer will be used [9].

The WindSonic device is compactly designed and housed within an IP65 rated casing. It is supplied with overvoltage protection, signal filtration and has a high sensor accuracy and resolution that is difficult to emulate with cheaper components. The prebuilt control circuitry also significantly reduces the complexity of this projects PCB design and simplifies the anemometers I/O requirements to two signalling leads.



Figure 5 - WindSonic 60 Anemometer

Specification [9]:

- Flexible operating voltage between 5 to 30V.
- Wind speed range between 0 to 60m/s at a resolution of 0.01m/s.
- Wind direction range between 1 to 360° at a resolution of 1°.
- Accuracy of $\pm 2\%$.
- Operating temperature between -40°C to 80°C.
- IP65 rated.
- Digital communication (internal AD converter) – Two signal leads.

Temperature and Humidity:

Temperature and humidity will be measured through the use of resistive sensors.

A material's resistance is incredibly linear to its temperature. By passing a known small current through this material, its temperature can be gauged by measuring the voltage dropped across it.

For humidity, a hygroscopic material is placed between two metallic plates. At low humidity, the hygroscopic material acts as a large resistor. As humidity increases, this material absorbs moisture and becomes more and more conductive, i.e. its resistance is inversely proportional to humidity. Similarly to temperature, knowing this resistance allows for humidity to be calculated.

Using this information, a small eight pin IC was found from Sensirion that measures both temperature and humidity in this way [10].



Figure 6 - Sensirion SHT3x-DIS

To maximise accuracy and efficiency of these sensors, there needs to be constant airflow from the environment being measured.

Specification [10]:

- Operating voltage between 2.15 and 5.50V.
- Humidity range between 0 to 100% at a resolution of 0.01%.
- Temperature range between -40 to 125°C at a resolution of 0.01°C.
- Accuracy of humidity and temperature is 1.5% and 0.1°C respectively.
- Analogue communication – Two signal pins.

Airborne Particle Count and VOC Levels:

Airborne particles are measured using a process known as light scattering [11]. When a laser is obstructed by matter, it will refract differently depending on the size, shape and density of the particle obstructing it.

Using a photodiode, this laser refraction can be used to induce a small electrical voltage that has a unique refraction signature to specific particles. By analysing these voltage signals, the type, and concentration of specific particles present within a sample can be determined.

For this project, the Sensirion SPS30 particle sensor shall be used [12]. This product is rated Particle Matter (PM) 10 meaning that particles below 10 μ m (microns) can be measured. According to the United States Environmental Agency (EPA), most airborne particles such as dust, pollen, and mould spores exist within the PM10 range [13].

For Volatile Organic Compound (VOC) measurements, this same sensor can be used. In the environment, VOC particles are referred to as pollutants and have negative health side effects during exposure. Some examples of VOC matter include pesticides, vehicle exhaust, aerosol, and natural gasses such as methane. These pollutants typically range within the PM2.5 scale, well within the capabilities of this sensor [14].

This device also requires access to a continuous air flow.



Figure 7 - Sensirion SPS30 PM10 Particle Sensor

Specification [12]:

- Operating voltage between 4.5 to 5.5V.
- Measurement range between 0.3 to 10 μ m at a resolution of 0.025 μ m.
- Accuracy of measurement is $\pm 10 \mu\text{g}/\text{m}^3$.
- Digital communication – Three signal leads

Brightness:

A photoresistor will be used to measure brightness within this project. A photoresistor has a high resistance when no light is present. When exposed to light, this resistance will drop with respect to the intensity of the light (luminosity). Using this resistance, a proportional luminosity can be calculated.

For this application, a NORPS-12 LDR will be used from Advanced Photonix [15].

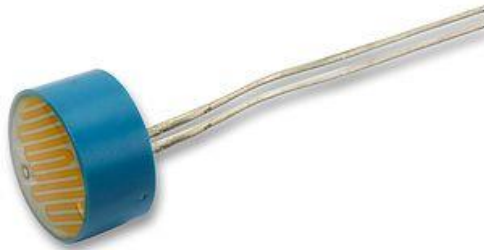


Figure 8 - NORPS-12 LDR Photoresistor

Specifications [15]:

- Operating voltage between 0 to 250V.
- Resistance range between 5.4k Ω and 12.6k Ω .
- Analogue sensor - two pins out.

UV:

To measure UV levels, a photodiode will be used. A UV photodiode filters all other light waves via a specially designed filter placed over the sensing area.

Diodes require energy to overcome their depletion zone and allow current to flow. In a UV photodiode, this energy is provided by the UV light. At low UV levels, there is minimal energy and thus no, or very little current will flow. Conversely as UV levels increase, so does the current. By measuring this current, a proportional UV level can therefore be calculated.

For this project, an Optoelectronics UV-035DQC photodiode shall be used [16].



Figure 9 - Optoelectronics UV-035DQC Photodiode

Specification [16]:

- Operating voltage between 1 to 5V.
- Operating current is 0.1mA.
- Signal range between 0 to 15mA at a resolution of 1 μ A.
- Analogue sensor – two pins out.

GPS:

To measure GPS position of the weather station, an ATGM336H-5N positional module from Hangzhou Microelectronics shall be used [17].

An antenna is supplied with this module that should be connected to the receiver pin on the integrated PCB. This will then receive signals from several satellites that will be able to triangulate the weather stations position on earth.

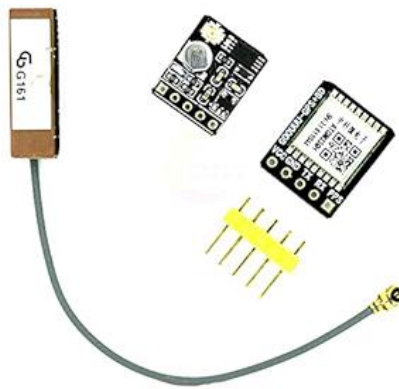


Figure 10 - ATGM336H-5N GPS Module

Specifications [17]:

- Operating voltage between 3.3 to 5.0V.
- Accuracy of within 4.0m
- Digital communication – three signal pins (only transmitter connection to PIC required)

Battery:

Using the component datasheets, the idle currents of each chosen sensor were used to determine an approximate Ampere Hour (AH) rating for a required battery. As GPS location will not change, it will only function at the beginning of testing. It has therefore been excluded from these calculations.

An approximated 15mA has been included for the chosen microcontroller.

Sensor	Idle Current
Wind Speed and Direction [9]	5.5 mA
Temperature and Humidity [10]	1.5 mA
PM and VOC [12]	15 mA
Brightness [15]	0.92 mA
UV Levels [16]	3.3 mA
Microcontroller	≈ 15mA
Total	≈ 41.22 mA

Table 2 - Current Capacity of Chosen Sensors

$$\text{Battery Life (Hours)} = \frac{\text{Capacity (mAh, Ah)}}{\text{Circuit Current (mA, A)}} \quad [18]$$

$$\text{Capacity (mAh, Ah)} = \text{Battery Life (Hours)} \times \text{Circuit Current (mA, A)}$$

$$\text{Capacity (mAh, Ah)} = (24 \times 14) \text{ hours} \times 41.22 \text{ mA}$$

$$\text{Capacity (mAh, Ah)} \approx \mathbf{13.85Ah \text{ Battery Required}}$$

From these calculations, an approximate 13.85Ah battery will be required to power this weather station over a fourteen-day test period. As for the voltage, it can be seen that none of the chosen sensors require more than a 5V supply therefore, a rechargeable Li-Ion battery at or above this rating shall be used.

Using these specifications, a Ansmann 14.54V Li-Ion battery was selected for this project [19].



Figure 11 - Ansmann 14.54V Li-Ion Re-Chargeable Battery

Specification [19]:

- Supply voltage of 14.54V.
- 14Ah capacity.
- Re-chargeable.
- Operating temperature between -20 to 60°C.

To reduce the supply voltage to the required 5V, a 7805-voltage regulator will be used [20].

USB:

To recharge the battery pack and transfer data between devices, an Amphenol SMT Type B USB Connector will be used [21].



Figure 12 - Amphenol Typer B USB Connector

Specification [21]:

- 5V operation.
- -55°C to 85°C temperature range.
- Four pin connection.

Memory Requirements

To determine memory requirements for this project, Table 3 was created showing the number of bytes required to store information for each sensor per sample. By choosing a sample rate, a total memory requirement was then calculated for the fourteen-day test period as seen in Table 4.

As the parameters being measured by a weather station are slow changing, it makes little sense to sample the data multiple time per second. Instead, all sensors excluding PM, VOC and GPS will take a measurement every twenty seconds.

The PM and VOC sensors will be set to sample every two seconds. Whilst its speed and direction may change slowly, wind continuously carries airborne particles. If too low a sample rate is selected, it is possible that desired particle data may be missed.

GPS will only be sampled at the start of the testing process. Three samples will be taken initially to ensure accuracy before the sensor is powered down for the remainder of the test period.

Parameter	I/O	Measurement Range	Resolution	No. of Possible Values	No. of Bits / Sample	No. of Bytes / Sample
Wind Speed	Digital	0 – 60 m/s	0.01 m/s	6000	13	2
Wind Direction	Digital	1 – 360°	1°	360	9	2
Temperature	Analogue	-40 – 125°C	0.1°C	1650	11	2
Humidity	Analogue	0 – 100%	0.01%	10000	14	2
Particle Count	Digital	0.3 – 10 µm	0.025 µm	280	9	2
VOC	Digital	0.3 – 10 µm	0.025 µm	280	9	2
Brightness	Analogue	5.4k – 12.6kΩ	0.1kΩ	72000	17	3
UV Level	Analogue	0 – 15 mA	1µA	15000	14	2
GPS: Longitude	Digital	1 – 360°	0.0001°	3600000	22	3
GPS: Latitude	Digital	1 – 360°	0.0001°	3600000	22	3

Table 3 - Memory Requirements per Sample

Parameter	Sample Frequency	Bytes / Hour	Bytes / Day	Bytes / Week	Bytes / Test
			(x24)	(x7)	(x2)
Wind Speed	Three per Minute	360B	8.64kB	60.48kB	120.96kB
Wind Direction	Three per Minute	360B	8.64kB	60.48kB	120.96kB
Temperature	Three per Minute	360B	8.64kB	60.48kB	120.96kB
Humidity	Three per Minute	360B	8.64kB	60.48kB	120.96kB
Particle Count	30 per Minute	3600B	86.4kB	604.8kB	1.21MB
VOC	30 per Minute	3600B	86.4kB	604.8kB	1.21MB
Brightness	Three per Minute	540B	12.96kB	90.72kB	181.44kB
UV Level	Three per Minute	360B	8.64kB	60.48kB	120.96kB
GPS: Longitude		Three per Test			27B
GPS: Latitude		Three per Test			27B
Total Memory Required ≈ 3.1MB					

Table 4 - Total Memory Requirement per Test Period

SD Card:

To store data from the weather station a micro-SD card will be used. This will require a micro-SD card holder to be integrated into the PCB design. For this application a Molex 104031 micro-SD card connector [22] and 64GB Kingston micro-SD card [23] shall be used.



Figure 13 - Molex Micro-SD Card Connector and Kingston Micro-SD Card

Microcontroller Selection

Using the Microchip selection tool [18], thousands of microcontrollers can be filtered based on desired parameters. Using the data gathered during component selection and by analysing the project specification, the following microcontroller parameters have been identified:

- 8-Bit PIC MCU.
- Six analogue inputs.
- Seven digital inputs.
- Two 8-Bit Timers.
- I²C compatibility.
- A programmable flash memory of 16kB for program script and known parameter datasets.
- USB compatibility.
- -40 to 60°C operating range.

Using these parameters, the selection tool found a total of 26 compatible microcontrollers. As any of these controllers would be suitable for application, the remaining microcontrollers were sorted by pin count to minimise PCB space. From this, three micro controllers were selected for further analysis:

1. PIC18F24J50
2. PIC18F25J50
3. PIC18F26J53

The specifications for these microcontrollers can be seen in Figure 11.

	PIC18F26J53 Microchip delete	PIC18F25J50 Microchip delete	PIC18F24J50 Microchip delete
Family	8-bit MCU	8-bit MCU	8-bit MCU
CPU Type	8-bit PIC MCU	8-bit PIC MCU	8-bit PIC MCU
Max CPU Speed (MHz)	48 MHz	48 MHz	48 MHz
FPU			
Operation Voltage	(2V-3.6V)	(2V-3.6V)	(2V-3.6V)
Temp Range	(-40 to 85)	(-40 to 85)	(-40 to 85)
Pin count	28	28	28
Program Memory Size (KB)	64 Flash	32 Flash	16 Flash
Error Correction Code Program Flash			
SRAM	3.7109375 KB	3.7109375 KB	3.7109375 KB
Data EEPROM/HEF (Bytes)			
Internal DRAM Type			
Internal DRAM Amount (MB)			
Low Power	Yes	Yes	Yes
ADC Input	13	10	10
Max ADC Resolution (Bits)	12	10	10
DAC Outputs			
Number of Op Amps			
Hardware Touch Peripheral			
UART	2	2	2
SPI	2	2	2
I2C	2	2	2
I2S			
SSC			
Number of USB Modules	1	1	1
USB Interface	FS Device	FS Device	FS Device
Number of CAN Modules			
Type of CAN module			
Ethernet			
Max 8-Bit Digital Timers	4	2	2
Max 16-Bit Digital Timers	4	3	3
Max 32-Bit Digital Timers			
Hardware RTCC/RTC	Yes	Yes	Yes
Max PWM outputs (including complementary)			
Number of PWM Time Bases			

Figure 14 - Microcontroller Comparison

Of the three selected microcontrollers, the PIC18F26J53 clearly has the highest performance without compromising on component size. A search into cost also highlighted only a £0.32 discrepancy between the selected microcontrollers. This was deemed negligible and the PIC18F26J53 [19] was selected for this project.

Connector Selection

An enclosure for this weather station will be built primarily out of glued PVC pipework. As a result, chosen cable connectors will not be required to be waterproof. Cable connectors will therefore only be required to be latching, to prevent self-loosening, and to operate within a -40 to 60° temperature range.

To meet these specifications, Molex wire to board connectors will be used [26]. Each component within this build will utilise a different Molex connect depending on their outputs. The specific connector chosen are shown in Table 5.

<u>Molex Product</u>	<u>Connector</u>	<u>Component</u>
22-05-7028 2 Pin Male Connector [27]	Battery Brightness Sensor UV Sensor	
679-5363 2 Pin Female Housing [28]	Battery Brightness Sensor UV Sensor	
22-27-2031 3 Pin Male Connector [29]	GPS	

22-01-3037 3 Pin Female Housing [30]	GPS	
22-27-2051 4 Pin Male Connector [31]	Temperature & Humidity Sensor Wind Speed & Direction Sensor PM & VOC Sensor	
22-01-2041 4 Pin Female Housing [32]	Temperature & Humidity Sensor Wind Speed & Direction Sensor PM & VOC Sensor	
08-50-0032 Crimps Terminals [35]	All Connectors	

Table 5 - Chosen Molex Connectors

Circuit Design

Power Distribution:

Through careful component selection, a 5V supply can be used for all components within this device. To achieve this, a 7805-voltage regulator will be used to reduce the 14.54V battery supply. Per the datasheet [20], two smoothing capacitors will be used to provide a stable, noise free output voltage as shown in Figure 15.

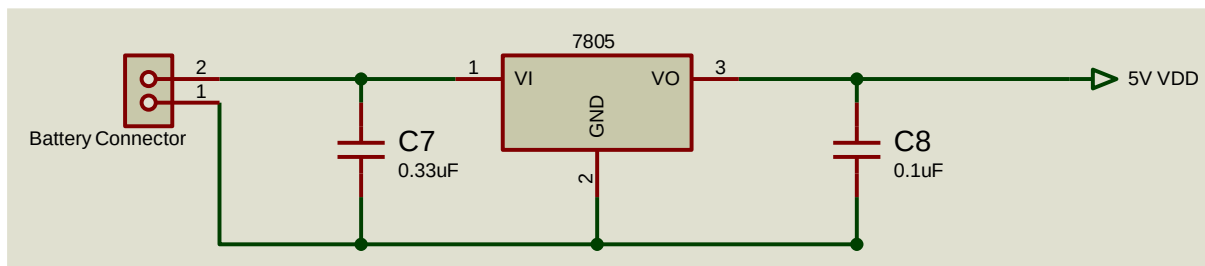


Figure 15 - 7805 Voltage Regulator Configuration

Sensor Signal Conditioning:

The output signal from each of the sensors may be susceptible to high frequency noise. A Low Pass Filter (LPF) with a relatively low cut off frequency of 50Hz shall be used to minimise this.

It is also important to provide each component with overvoltage protection. This can be achieved using a 5.1V Zener diode. By connecting the 5.1V Zener diode across the LPF, a simple signal conditioning circuit can be created.

To calculate the component sizes for a 50Hz LPF, the following calculation were used:

$$\text{Cutoff Frequency (Fc)} = \frac{1}{2\pi \times \text{Resistance (R)} \times \text{Capacitance (C)}}$$

$$\text{Capacitance (C)} = \frac{1}{2\pi \times \text{Resistance (R)} \times \text{Cutoff Frequency (Fc)}}$$

Let $R = 1k\Omega$ and $F_c = 50\text{Hz}$

$$\text{Capacitance (C)} = \frac{1}{2\pi \times 1000\Omega \times 50\text{Hz}} = 3.18\mu\text{F} = \textbf{Standard Size of } 3.3\mu\text{F}$$

Using the calculated values, the signal conditioning circuit shown in Figure 16 was created.

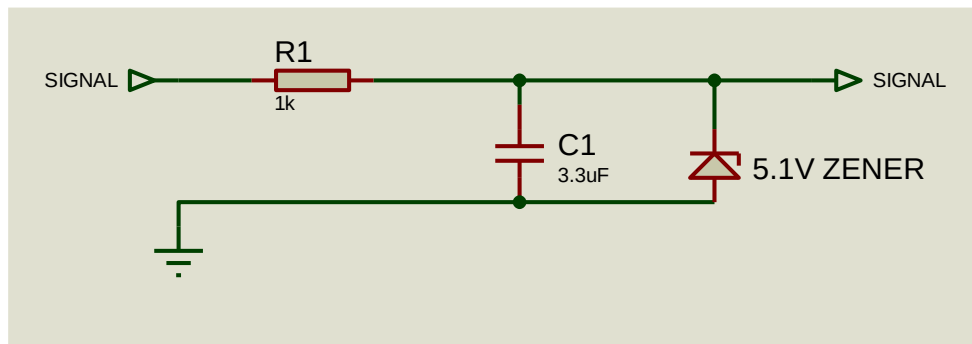


Figure 16 – 50Hz LPF with 5V Overvoltage Protection

LED:

An LED will be used to indicate operation of the device. This will be powered directly from microcontroller pin RC4 and will be programmed to flash for one second every ten. A 1kΩ resistor will be connected in series with the LED to limit current.

Circuit Schematic:

Using Easy-PC software, the following schematic diagrams were created for this device.

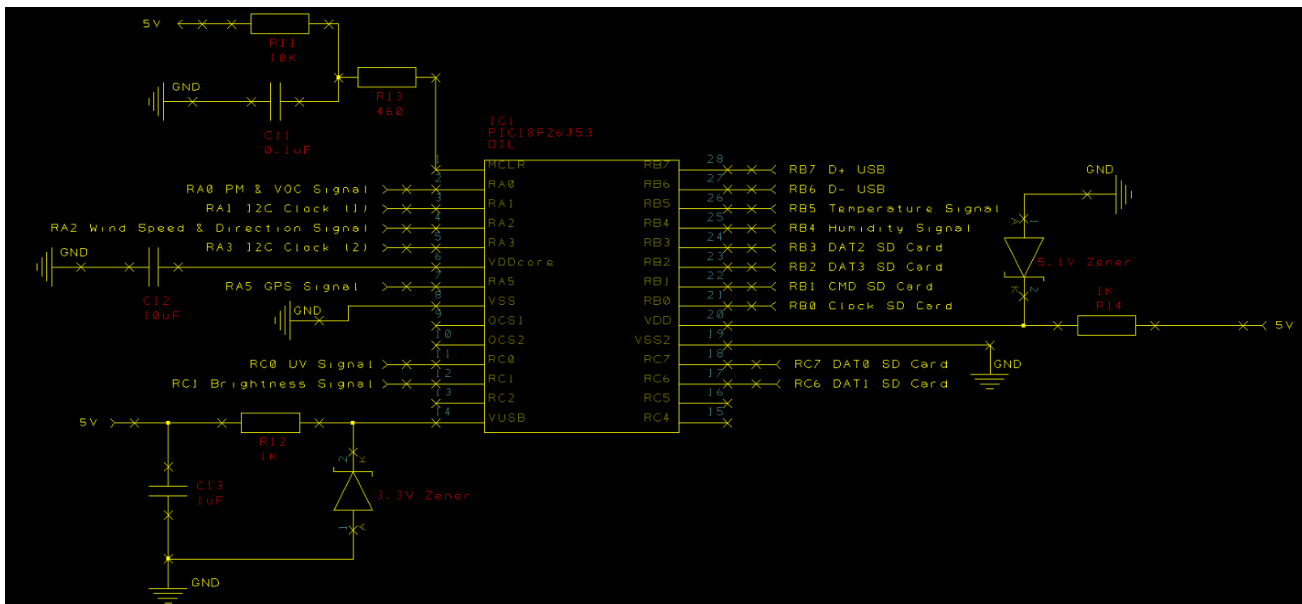


Figure 17 - Schematic of Microcontroller Connections

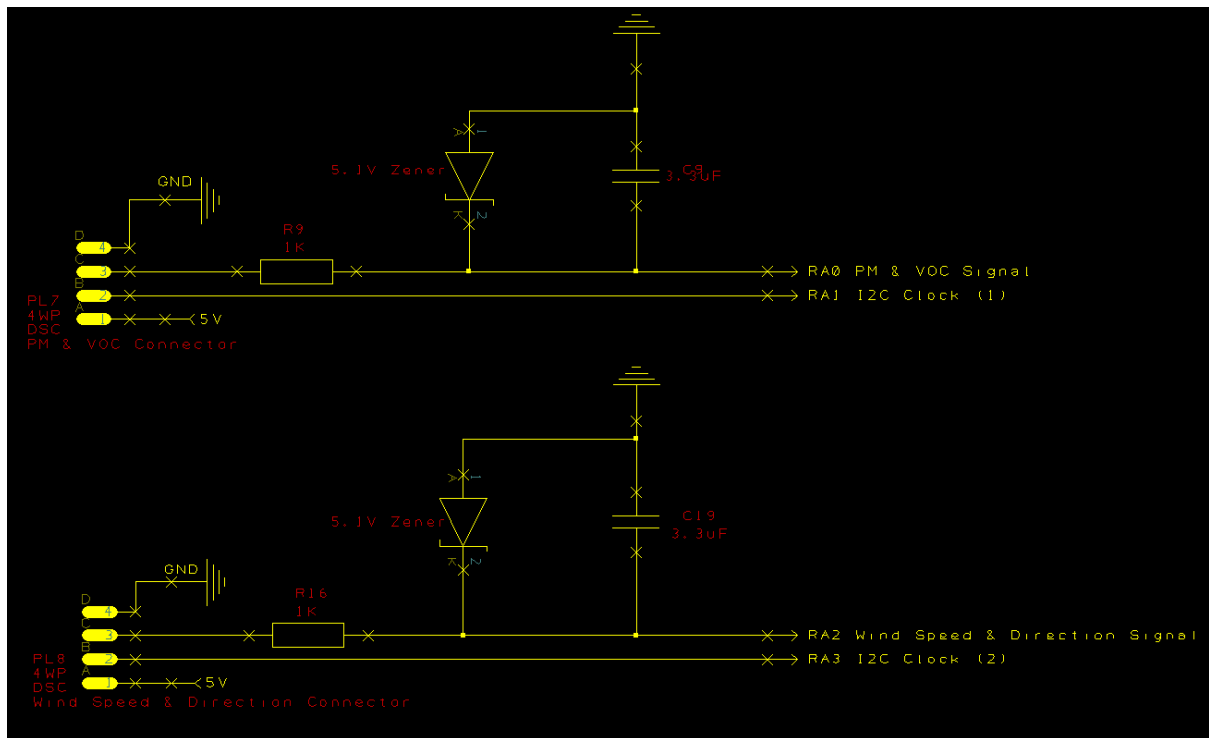


Figure 18 - Schematic of PM & VOC and Wind Speed & Direction Sensors

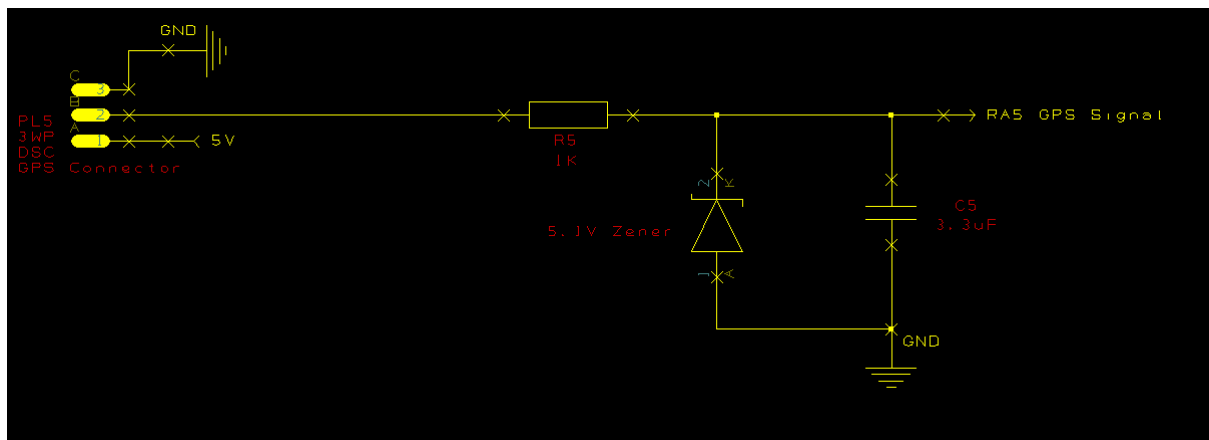


Figure 19 - Schematic of GPS Connection to Microcontroller

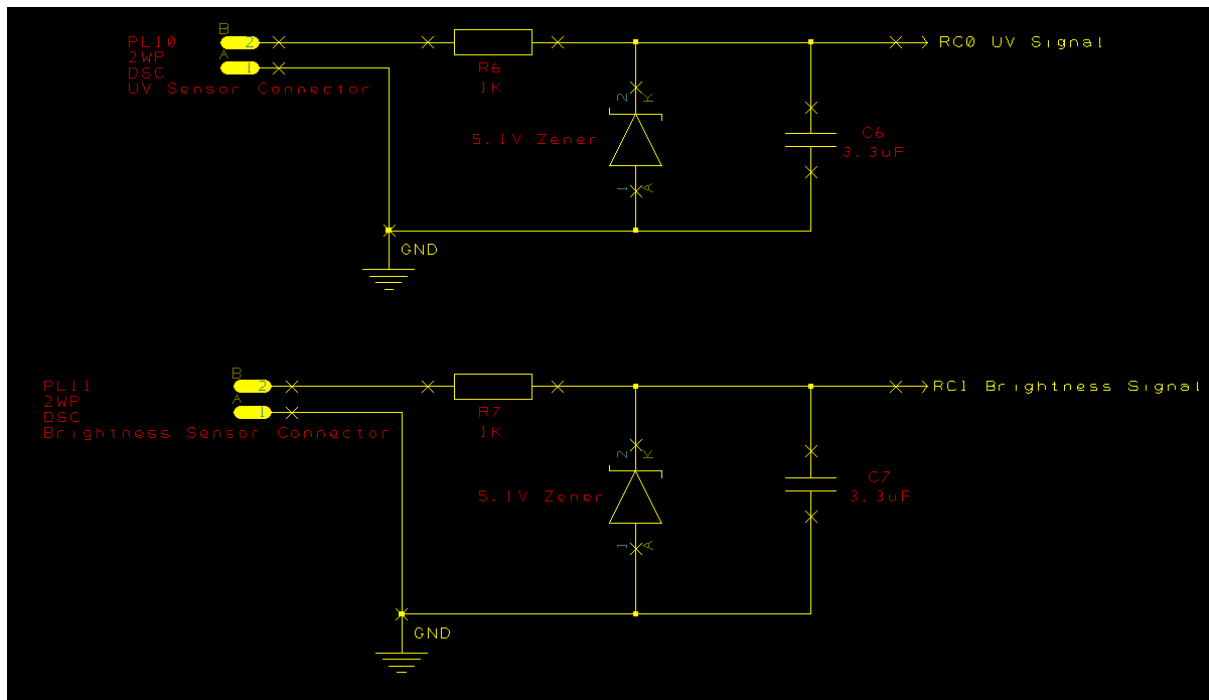


Figure 20 - Schematic of UC and Brightness Sensor Connections

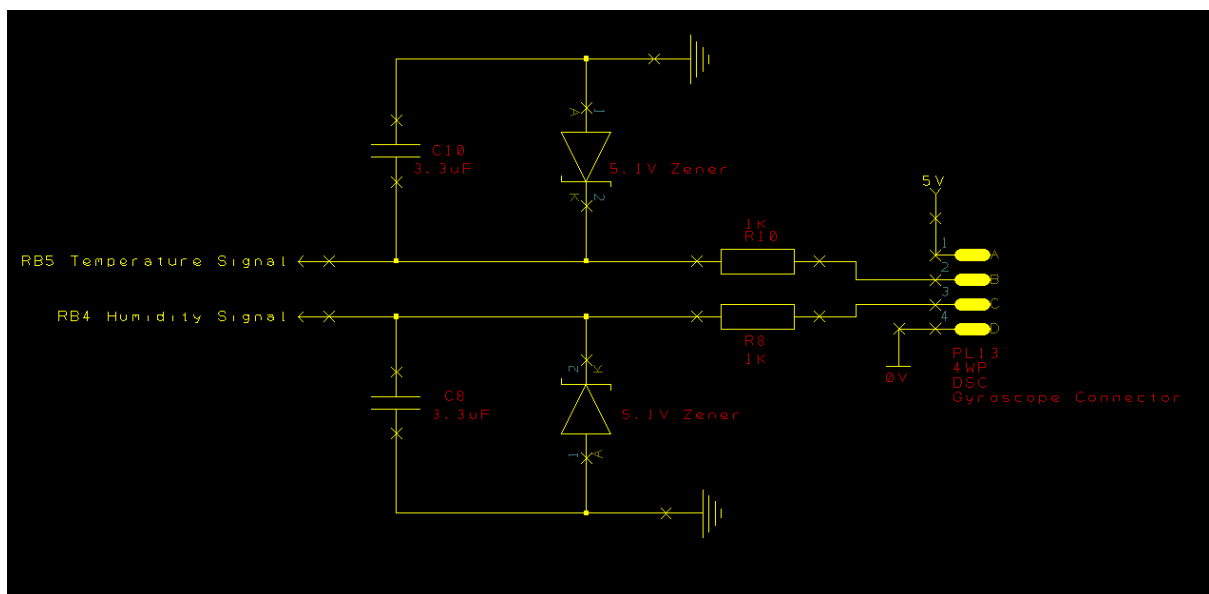


Figure 21 - Schematic of Temperature & Humidity Sensor Connections

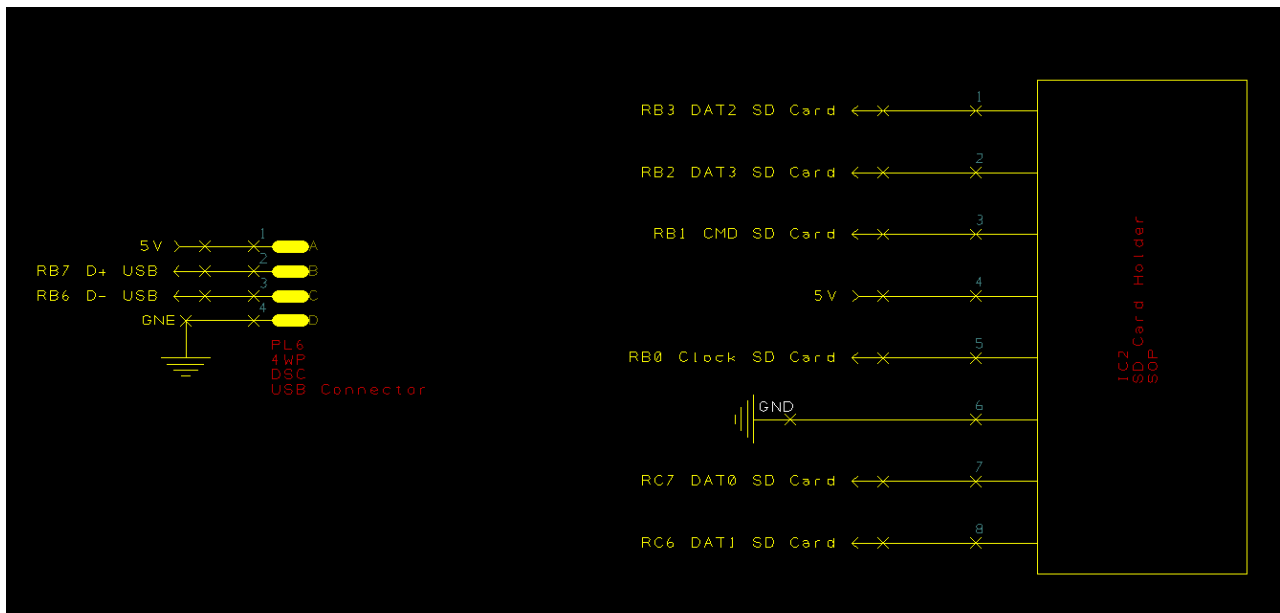


Figure 22 - Schematic of USB and SD Card Holder Connections

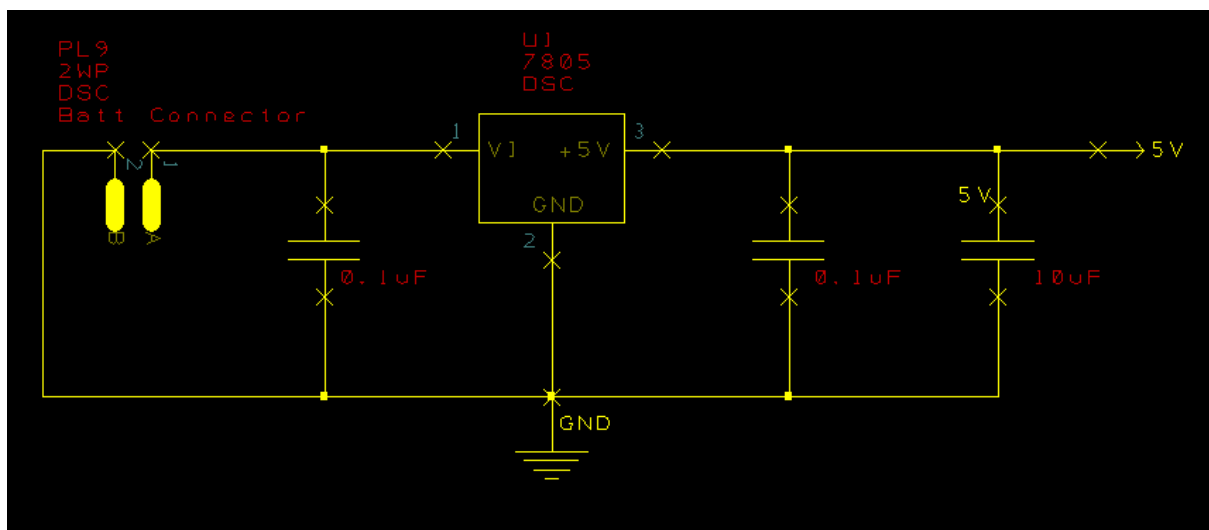


Figure 23 - Schematic of 7805 Voltage Regulator Connections

PCB Design:

Once the schematics were complete, a PCB design was created utilising the same software. The design shown in Figure 24 shows the final positioning and routing between each component. A dual layer board was used to allow for efficient routing. The hatched section highlights the area of copper pour used to create a ground plane on the board. This pour also aids in reducing electrical noise.

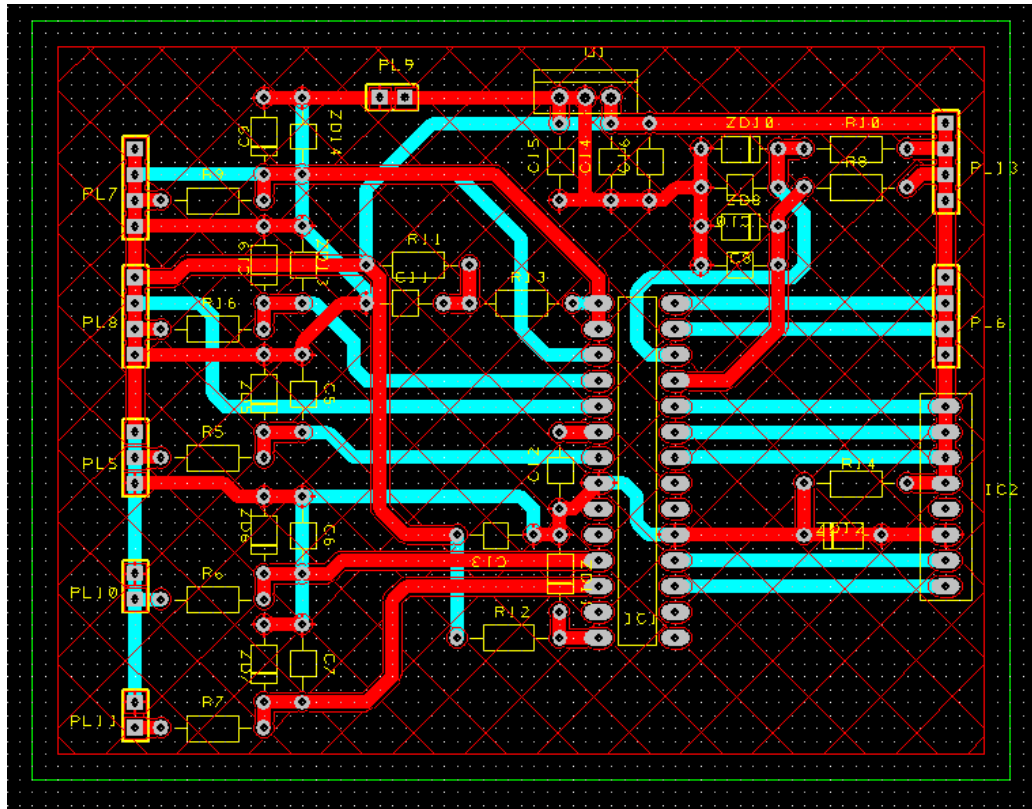


Figure 24 – Project PCB Design

PCB 3D Model:

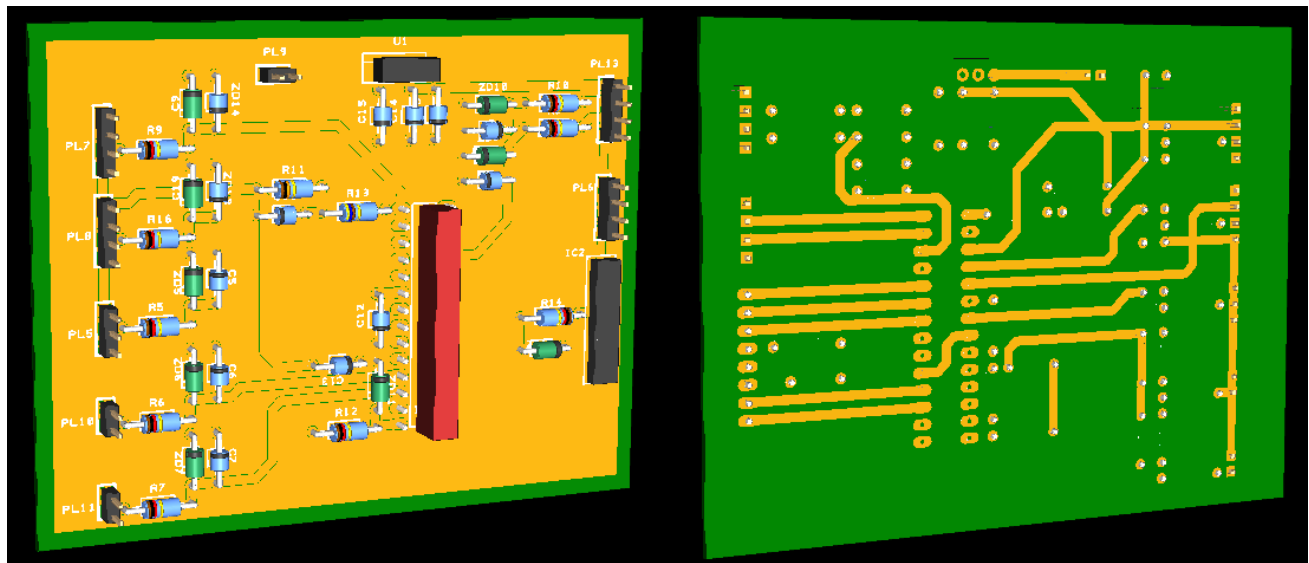


Figure 25 - 3D Model of PCB Design

PCB Cost:

Using the Easy-PC design files, JLCPCB was used to provide a production cost of the PCB. This totalled £2.55 per board.

Category	Option	Price
Charge Details	Special Offer	£ 1.60
	Via Covering	£ 0.00
	Surface Finish	£ 0.96
Build Time	PCB: 2 days	£ 0.00
	24 hours	£ 5.67
Calculated Price		£ 2.55
Additional charges may apply for special cases		
Shipping Estimate		£ 16.77
DHL Express Worldwide		2-4 business days
Weight		0.28kg

Figure 26 - JLCPCB PCB Quote

Enclosure

The enclosure for this weather station will be built using PVC pipework. Utilising the 45mm cable access of the WindSonic anemometer, a PVC pipe will be inserted and glued directly into the sensor housing. This will feed into a larger, capped, PVC pipe that will house the battery and PCB whilst also providing structural stability. PVC glue will be used to create a waterproof bond between all components. A basic concept of this can be seen in Figure 27.

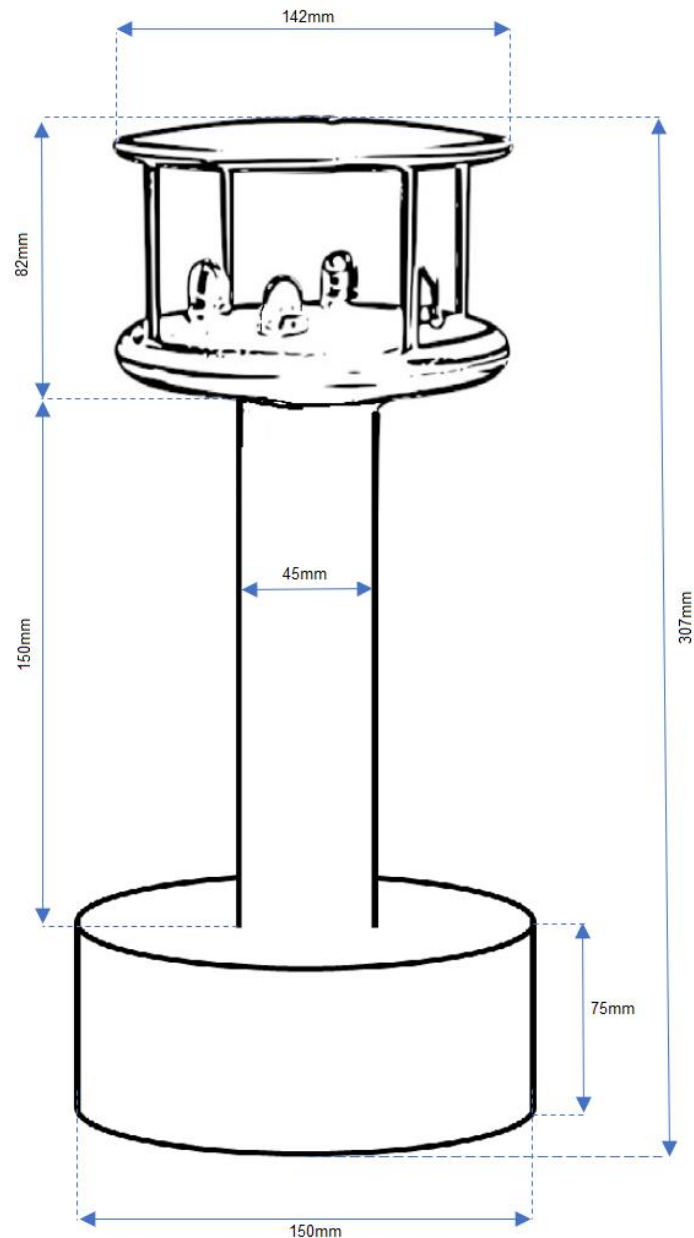


Figure 27 - Basic Design Concept

For correct use, the brightness and UV sensors will be built into the anemometer canopy. They will be bonded to the canopy using a waterproof sealant. The cables for these sensors will be fed through the hollow canopy struts and into the PVC pipe.

To allow airflow for temperature, humidity, PM and VOC sensing, angled air vents will be moulded onto the smaller PVC pipe as seen on the Ecowitt product research previously. This will allow continuous airflow whilst preventing rainwater from entering the device.

Project Costing

Components	Source	Quantity	Cost (inc. VAT)
WindSonic 60 Anemometer	WindSonic	1	£299
Sensirion SHT3x-DIS	Farnell	1	£2.13
Sensirion SPS30	Parallax	1	£37.34
NORPS-12 LDR	Farnell	2	£2.83
Optoelectronics UV-035DQC	RS Components	1	£23.34
ATGM336H-5N GPS	TinyTronics	1	£9.46
Ansmann 14.54V Li-Ion Battery	RS Components	1	£100.97
Amphenol SMT Type B USB Connector	RS Components	1	£0.28
64GB Kingston Micro-SD Card	Amazon	1	£5.83
PIC18F26J53	Mouser	1	£3.52
Molex 22-05-7028	RS Components	3	£1.39
Molex 22-01-3027	RS Components	3	£1.05
Molex 22-27-2031	RS Components	1	£1.19
Molex 22-01-3037	RS Components	1	£1.13
Molex 22-27-2051	RS Components	3	£0.37
Molex 22-01-2041	RS Components	3	£0.15
Molex 08-50-0032	RS Components	21	£2.75
7805 Voltage Regulator	Farnell	1	£0.56
PCB	JLCPBC	1	£2.55
1kΩ Resistor	RS Components	9	£1.75
0.1µF Capacitor	Farnell	3	£0.35
1µF Capacitor	Farnell	1	£0.81
3.3µF Capacitor	Farnell	7	£0.18
10µF Capacitor	Farnell	1	£0.22
5.1V Zener Diode	Farnell	8	£1.28
3.3V Zener Diode	Farnell	1	£0.52
45mm PVC Pipe	B&Q	1m	£12.00

150mm PVC Pipe	B&Q	1m	£14.75
0.3m² PVC Sheet	B&Q	1	£4.99
PVC Glue	B&Q	1	£12.00
Total Component Cost - £544.69			

Table 6 - Project Costing

Software Structure

The basic software structure for this weather station can be seen in Figures 28, 29 and 30. The software structure has been broken down into three sections.

1. Mode Selection:

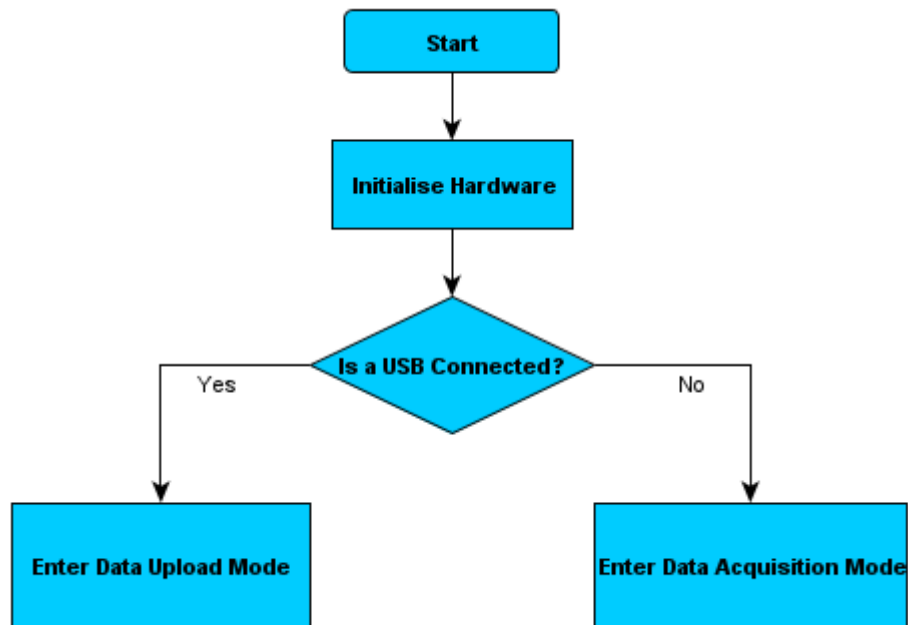


Figure 28 - Software Structure for Mode Selection

Depending on whether or not a USB is connected, the software will enter either “Data Upload” or “Data Acquisition” mode.

2. Data Upload Mode:

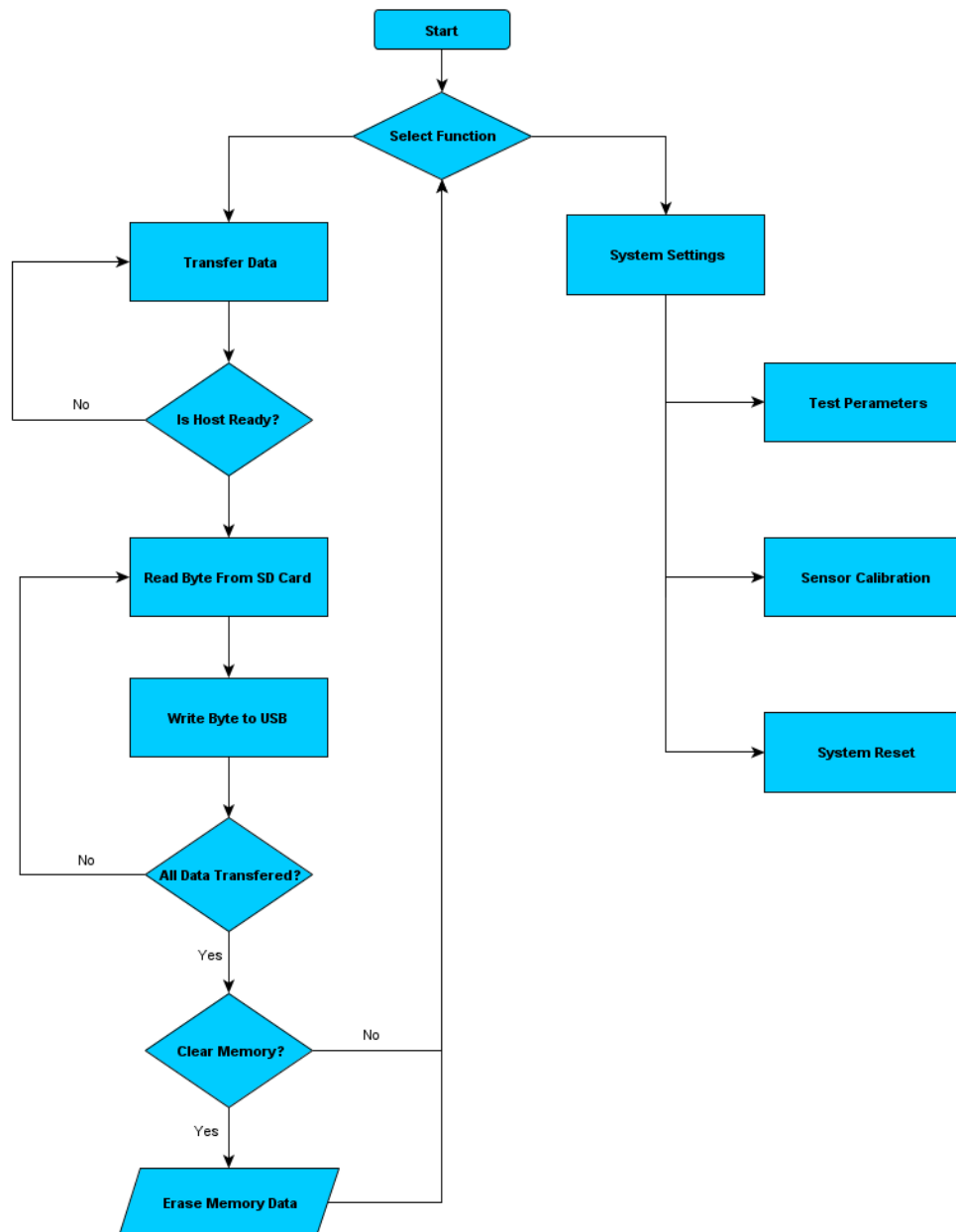


Figure 29 - Software Structure for Data Upload

This mode will allow the user to transfer test data from the weather station to an external device. System settings can also be accessed to change test parameters, calibrate sensors or to reset the system.

3. Data Acquisition Mode:

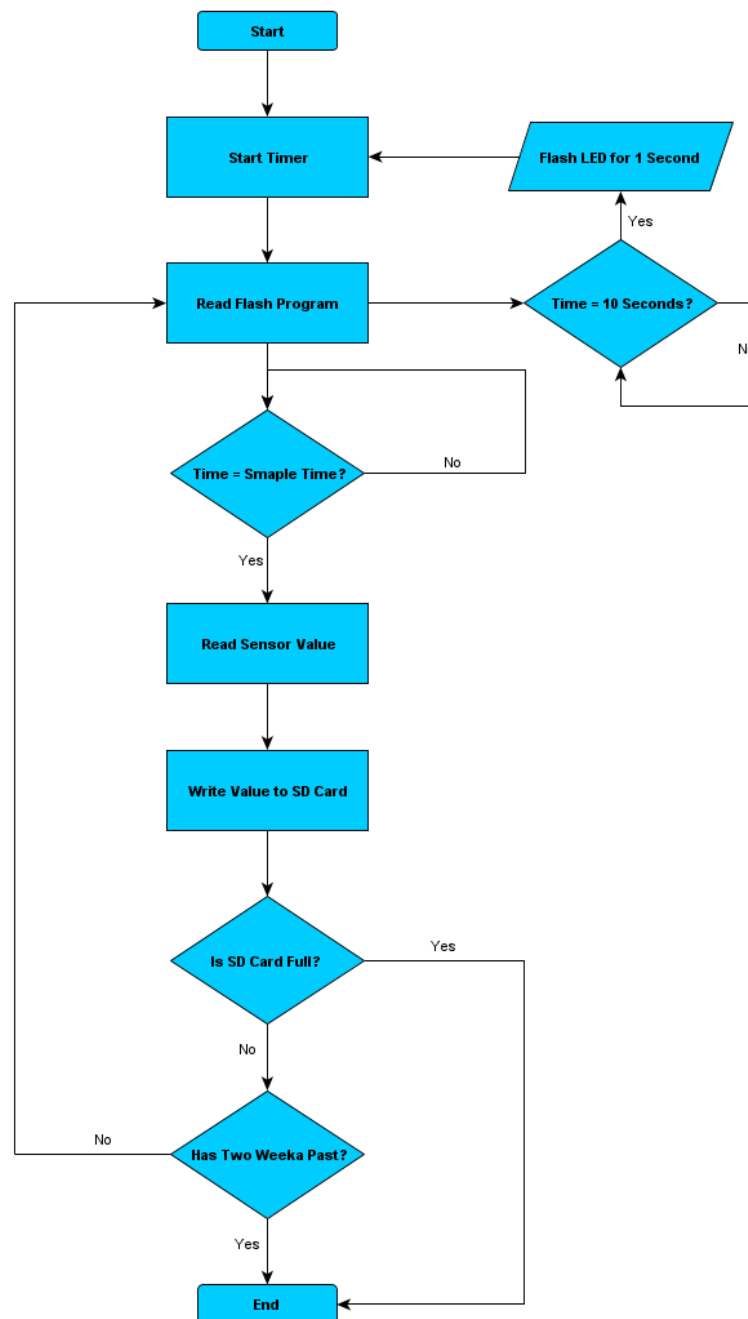


Figure 30 - Software Structure for Data Acquisition

Data acquisition mode shows the software structure during testing. It highlights the basic program loop for each sensor. Depending on the specific sensor, the “Sample Time” within the structure will change.

Design Improvements

1. Battery Sustainability:

Due to the environments weather stations operate, it is possible to harness energy from solar and wind power. This would extend battery life and if done efficiently, may allow the weather station to continuously self-sustain.

To achieve this, a cup anemometer could be used to harness wind energy. The shaft output from this anemometer would then be coupled to a small generator that could feed its output voltage back to the battery. Additionally, small solar panels could be integrated into the design for a similar use.

Whilst improving battery life, this may also allow for a much smaller and cheaper battery pack to be selected.

2. Sample Rate:

When initially designing this weather station, memory sizing for a two-week testing period was a major concern. As a result, a moderate sample rate for each sensor was selected. After calculating memory requirements, it was found that only 3.1MB would be needed to sample at the chosen rates.

This shows that the sample rate for each sensor can be significantly increased without modifications to the chosen 64GB SD card storage. This would provide a higher accuracy and precision of results, especially from faster changing parameters such as PM and VOC.

3. VOC Alarm:

From initial research, many VOCs were found to be dangerous such as CO₂, flammable gases, and airborne pollutions. It is possible that when these compounds are detected in certain concentration that some form of alarm system could be triggered. This alarm could be localised in the form of a siren or even sent as a wireless signal to an offsite device utilising the GPS antenna.

This technology could be used to combat wildfires, monitor gas concentrations in habitable areas and for a plethora of wildlife conservation applications.

Conclusion

Throughout this project, it has been shown how, through the use of basic electronic components and sensing devices, a hobbyist level weather station can be designed.

Each of the chosen components meet project specification and have been integrated into the PCB design per datasheet instructions. With correct software programming, it is believed that this device will operate as required.

The PCB itself, is efficiently laid out utilising a two layered design to correctly connect all components. A copper pour has been integrated to create a ground plane, reducing connection requirements, and aiding in the reduction of electrical noise within the device.

The enclosure will provide a waterproof housing for all electronic components and whilst also allowing for sufficient airflow for temperature, humidity, PM, and VOC monitoring. The UV and brightness sensors have also been mounted in an optimal location for application.

Whilst it is believed this device will operate as intended, it is strongly recommended that additional research be conducted into trying to self-sustain the battery. Relative to the rest of the device, the battery is very large and expensive. By harnessing wind and solar energies, a charging circuit could be integrated that would eliminate the biggest drawback to this current design.

Bibliography

- [1] Sainlogic, "SAINLOGIC PROFESSIONAL WEATHER STATION - OPERATION MANUAL," [Online]. Available: https://www.sainlogic.com/media/hexaattachment/products/attachments/WS3500mmanual_English.pdf. [Accessed 11 12 2023].
- [2] Maximum Weather Instruments, "What are the Different Types of Rain Gauges?," 15 06 2020. [Online]. Available: <https://www.maximum-inc.com/learning-center/what-are-the-different-type-of-rain-gauges/#:~:text=The%20Standard%20Rain%20Gauge&text=These%20gauges%20work%20by%20catching,by%20a%20factor%20of%2010..> [Accessed 11 12 2023].
- [3] Ecowitt, "Wittboy Pro," Ecowitt, [Online]. Available: <https://shop.ecowitt.com/en-gb/products/wittboy-pro>. [Accessed 13 12 2023].
- [4] J. E. S. A. S. G. Ivan Adi Kuncara, "Development of Ultrasonic Anemometer," Department of Physics, Faculty of Science and Mathematics, Diponegoro University, 2020. [Online]. Available: https://www.e3s-conferences.org/articles/e3sconf/pdf/2020/62/e3sconf_icenis2020_15011.pdf. [Accessed 13 12 2023].
- [5] Eurosensor, "What is a Piezoelectric Sensor?," Eurosensor, [Online]. Available: <https://www.variohm.com/news-media/technical-blog-archive/what-is-a-piezoelectric-sensor->. [Accessed 13 12 2023].
- [6] Netatmo, "Technical specifications," Netatmo, [Online]. Available: <https://www.netatmo.com/en-gb/smart-anemometer/specifications>. [Accessed 14 12 2023].
- [7] Circuit Globe, "Classifications of Hygrometer," Circuit Globe, [Online]. Available: <https://circuitglobe.com/hygrometer.html>. [Accessed 14 12 2023].
- [8] WindSonic, "Wind System WindSonic™ Ultrasonic Sensor," WindSonic, [Online]. Available: https://r-p-r.co.uk/downloads/windsystems/015SL065_1_WS_WindSonic_datasheet.pdf. [Accessed 22 12 2023].
- [9] Sensirion, "Datasheet SHT3x-DIS," Sensirion, 02 2019. [Online]. Available: <https://docs.rs-online.com/6b89/0900766b816bf6a6.pdf>. [Accessed 22 12 2023].
- [1] LWS, "HOW DO LIGHT SCATTERING AIRBORNE PARTICLE COUNTERS WORK?," LWS, [Online]. Available: <https://www.golighthouse.com/en/blog/how-do-light-scattering-airborne-particle-counters-work-497/>. [Accessed 24 12 2023].

- [1] Sensirion, "Datasheet SPS30," Sensirion, 09 2023. [Online]. Available:
1] <https://www.farnell.com/datasheets/3981295.pdf>. [Accessed 2023 12 24].
- [1] EPA, "Particulate Matter (PM) Basics," EPA, 11 07 2023. [Online]. Available:
2] <https://www.epa.gov/pm-pollution/particulate-matter-pm-basics#:~:text=PM%20stands%20for%20particulate%20matter,seen%20with%20the%20naked%20eye..> [Accessed 24 12 2023].
- [1] EPA, "Volatile Organic Compounds' Impact on Indoor Air Quality," EPA, 15 08
3] 2023. [Online]. Available: <https://www.epa.gov/indoor-air-quality-iaq/volatile-organic-compounds-impact-indoor-air-quality>. [Accessed 24 12 2023].
- [1] Advanced Photonix, "NORPS-12," Advanced Photonix, [Online]. Available:
4] <https://www.farnell.com/datasheets/3759787.pdf>. [Accessed 26 12 2023].
- [1] Optoelectronics, "Inversion Layer and Planar Diffused Silicon Photodiodes,"
5] Optoelectronics, [Online]. Available: <https://docs.rs-online.com/45a3/0900766b816cbc1a.pdf>. [Accessed 26 12 2023].
- [1] Hangzhou Microelectronics, "BDS/GNSS Whole Constellation," Hangzhou
6] Microelectronics, [Online]. Available: [file:///C:/Users/G-Dav/Downloads/ATGM336H%20\(2\).pdf](file:///C:/Users/G-Dav/Downloads/ATGM336H%20(2).pdf). [Accessed 28 12 2023].
- [1] E. E. Applications, "How to Calculate Battery Life? (Battery Capacity mAh, Ah),"
7] 14 03 2023. [Online]. Available:
https://www.youtube.com/watch?v=848yXCx0Q4s&ab_channel=ElectricalElectronicsApplications. [Accessed 02 01 2024].
- [1] Anasmann, "2447-3099-X20_0DA MODELLi-Ion-14.54C-14Ah-3S4P-block-PTC,"
8] Anasmann, 2016. [Online]. Available: <https://docs.rs-online.com/be2e/A700000007962168.pdf>. [Accessed 03 01 2024].
- [1] ST Microelectronics, "Positive voltage regulator ICs - L78," ST Microelectronics, 09
9] 2018. [Online]. Available:
<https://4donline.ihs.com/images/VipMasterIC/IC/SGST/SGST-S-A0006334694/SGST-S-A0006334694-1.pdf?hkey=52A5661711E402568146F3353EA87419>. [Accessed 03 01 2024].
- [2] FCI, "MICRO USB 2.0 CONNECTORS," Amphenol, [Online]. Available:
0] <https://docs.rs-online.com/6e70/A700000008998149.pdf>. [Accessed 03 01 2024].
- [2] Molex, "1040310811," Molex, [Online]. Available: <https://docs.rs-online.com/cb8c/0900766b815e9d5b.pdf>. [Accessed 01 01 2024].
- [2] Kingston Technologies, "Canvas Select Plus microSD," Kingston Technologies,
2] [Online]. Available: <https://docs.rs-online.com/cf5b/A700000006563916.pdf>. [Accessed 01 01 2024].

- [2 Microchip, "MICROCHIP ADVANCED PART SELECTOR," Microchip, 2024.
- 3] [Online]. Available: <https://www.microchip.com/maps/microcontroller.aspx>. [Accessed 01 01 2024].
- [2 Microchip, "PIC18F47J53 FAMILY," Microchip, 2016. [Online]. Available:
- 4] <https://ww1.microchip.com/downloads/aemDocuments/documents/OTH/Product Documents/DataSheets/30009964C.pdf>. [Accessed 01 01 2024].
- [2 Molex, "Wire to Board Connectors," Molex, 2024. [Online]. Available:
- 5] <https://www.molex.com/en-us/products/connectors/wire-to-board-connectors>. [Accessed 01 01 2024].
- [2 Molex, "Molex KK 254 Series Right Angle Through Hole Pin Header, 2
- 6] Contact(s), 2.54mm Pitch, 1 Row(s), Unshrouded," Molex, [Online]. Available: <https://uk.rs-online.com/web/p/pcb-headers/1732916?gb=s>. [Accessed 03 01 2024].
- [2 Molex, "Molex, 2695 Female Connector Housing, 2.54mm Pitch, 2 Way, 1 Row,"
- 7] Molex, [Online]. Available: <https://uk.rs-online.com/web/p/wire-housings-plugs/6795363?gb=s>. [Accessed 03 01 2024].
- [2 Molex, "Molex KK 254 Series Straight Through Hole Pin Header, 3 Contact(s),
- 8] 2.54mm Pitch, 1 Row(s), Unshrouded," Molex, [Online]. Available: <https://uk.rs-online.com/web/p/pcb-headers/4838477?gb=s>. [Accessed 03 01 2024].
- [2 Molex, "Molex, KK 254 Female Connector Housing, 2.54mm Pitch, 3 Way, 1
- 9] Row," Molex, [Online]. Available: <https://uk.rs-online.com/web/p/wire-housings-plugs/6795375>. [Accessed 03 01 2024].
- [3 Molex, "Molex KK 254 Series Straight Through Hole Pin Header, 5 Contact(s),
- 0] 2.54mm Pitch, 1 Row(s), Unshrouded," Molex, [Online]. Available: <https://uk.rs-online.com/web/p/pcb-headers/4838499?gb=s>. [Accessed 03 01 2024].
- [3 Molex, "Molex, KK 254 Female Connector Housing, 2.54mm Pitch, 4 Way, 1
- 1] Row," Molex, [Online]. Available: <https://uk.rs-online.com/web/p/wire-housings-plugs/6795307?gb=s>. [Accessed 03 01 2024].
- [3 Molex, "Molex KK 4809 Crimp Terminal Contact, Female, 0.05mm² to 0.35mm²,
- 2] 30AWG to 22AWG, Tin Plating," Molex, [Online]. Available: <https://uk.rs-online.com/web/p/crimp-contacts/0467598>. [Accessed 03 01 2024].
- [3 Sainlogic, "Sainlogic Profi WLAN Weather Station," Sainlogic, [Online]. Available:
- 3] <https://www.amazon.co.uk/Sainlogic-Weather-Station-Outdoor-Sensor/dp/B07TVMQ2CK>. [Accessed 11 12 2023].
- [3 Microchip, "MICROCHIP ADVANCED PART SELECTOR," Microchip, 2023.
- 4] [Online]. Available: <https://www.microchip.com/maps/microcontroller.aspx>. [Accessed 22 10 2023].

- [3 FCI, "MICRO USB 2.0 CONNECTORS," Amphenol, [Online]. Available: <https://docs.rs-online.com/6e70/A700000008998149.pdf>. [Accessed 11 11 2023].
- [3 RS, "Molex KK 254 Series Right Angle Through Hole Pin Header, 2 Contact(s), 6] 2.54mm Pitch, 1 Row(s), Unshrouded," Molex, [Online]. Available: <https://uk.rs-online.com/web/p/pcb-headers/1732916?gb=s>. [Accessed 16 11 2023].
- [3 RS, "Molex, 2695 Female Connector Housing, 2.54mm Pitch, 2 Way, 1 Row," 7] Molex, [Online]. Available: <https://uk.rs-online.com/web/p/wire-housings-plugs/6795363?gb=s>. [Accessed 16 11 2023].
- [3 RS, "Molex KK 254 Series Straight Through Hole Pin Header, 3 Contact(s), 8] 2.54mm Pitch, 1 Row(s), Unshrouded," Molex, [Online]. Available: <https://uk.rs-online.com/web/p/pcb-headers/4838477?gb=s>. [Accessed 16 11 2023].
- [3 RS, "Molex, KK 254 Female Connector Housing, 2.54mm Pitch, 3 Way, 1 Row," 9] Molex, [Online]. Available: <https://uk.rs-online.com/web/p/wire-housings-plugs/6795375>. [Accessed 16 11 2023].
- [4 RS, "Molex KK 254 Series Straight Through Hole Pin Header, 5 Contact(s), 0] 2.54mm Pitch, 1 Row(s), Unshrouded," Molex, [Online]. Available: <https://uk.rs-online.com/web/p/pcb-headers/4838499?gb=s>. [Accessed 16 11 2023].
- [4 RS, "Molex, KK 254 Female Connector Housing, 2.54mm Pitch, 4 Way, 1 Row," 1] Molex, [Online]. Available: <https://uk.rs-online.com/web/p/wire-housings-plugs/6795307?gb=s>. [Accessed 16 11 2023].
- [4 RS, "Molex KK 4809 Crimp Terminal Contact, Female, 0.05mm² to 0.35mm², 2] 30AWG to 22AWG, Tin Plating," Molex, [Online]. Available: <https://uk.rs-online.com/web/p/crimp-contacts/0467598>. [Accessed 16 11 2023].
- [4 Molex, "Molex KK 254 Series Straight Through Hole Pin Header, 5 Contact(s), 3] 2.54mm Pitch, 1 Row(s), Unshrouded," Molex, [Online]. Available: <https://uk.rs-online.com/web/p/pcb-headers/6701336?gb=s>. [Accessed 03 01 2024].
- [4 Molex, "Molex, KK 254 Female Connector Housing, 2.54mm Pitch, 5 Way, 1 4] Row," Molex, [Online]. Available: <https://uk.rs-online.com/web/p/wire-housings-plugs/6795322P?gb=s>. [Accessed 03 01 2024].