

weatherstation

by Daniel Lennon

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Design of a micro controller based
Portable Weather monitoring/Air Quality
measurement/logging system.

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Level 6.

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1. Introduction.

The purpose of this report is to detail and describe the design of a micro controller based, portable weather and air quality monitoring system. The system must be able to record the data received from the sensors for a period of 7 days, with each sensor taking readings at pre-determined frequencies. The data parameters required for this project are the following:

- Temperature.
- Humidity.
- Wind speed.
- Wind direction.
- Air borne particle count.
- Sunlight brightness.
- UV levels.
- GPS position

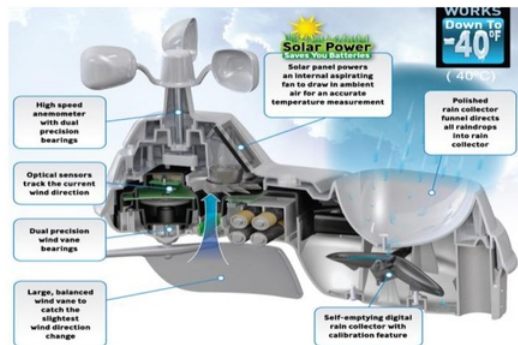
Included in this report is a brief review and comparison of existing weather monitoring systems and their functions. In addition, a review of sensor types is included and justifications for those selected for the design are given, the micro controller choice will be

provided and justified as well as a suggested package design, Memory storage size, battery type and size, Circuit diagrams, PCB design and a Software structure diagram.

2. Existing products.

There are many different types of weather monitoring systems available ranging massively in functionality and price. Following are a few examples of these systems, their functions and a brief chart comparing the features and prices of the selected systems.

2.1 Acurite 5 in 1 weather station.



[1].

Features.

- Temperature sensor.
- Humidity sensor.
- Wind speed.
- Wind direction.
- rainfall level.

This station requires an additional sensor display to manage the data received.

2.2 HOBO® U30-NRC Station Starter System (U30-NRC-SYS-C)



[2].

Features.

- HOBO U30 NRC data logger with 10 inputs.
- 3W Solar Panel.
- Temperature/RH Smart Sensor with 2-meter cable.
- Wind Speed Smart Sensor with 3-meter cable.
- Wind Direction Smart Sensor with 3-meter cable.
- Full Cross arm for Wind Speed/Direction sensors.
- Solar Radiation Shield for Temperature & RH sensor.

In addition to the parameters mentioned above many additional smart sensors can be attached and read easily.

2.3 Oregon Scientific WMR300A Ultra-Precision Professional Weather System



[3].

Features.

- Adjustable recording frequency (max 3 years).
- Wireless transmission up to 300 m.
- Touch screen console.
- Anemometer.
- Thermo/hydro sensor.
- Rain gauge.
- Solar sensor transmission.
- PC software: Weather OS Pro.
- Console firmware: updatable.

This system can also integrate up to 8 additional sensors sold separately.

2.4 Prodata Systems: Davis Vantage Vue Weather Station.



Features.

Measures all six standard weather parameters.

- Wind speed & direction.
- Air temperature.
- Humidity.
- Pressure.
- Rainfall.

Additionally displays:

- Inside temperature/humidity at the console location.
- Derived readings such as Dew Point and Wind Chill Temperatures.
- Calendar data, date/time, sunrise/sunset times, moon phase etc.

The Vantage Vue station consists of just two components: the display console shown here and a single all-in-one outside sensor assembly.

[4].

2.5 comparison of weather stations.

	Acurite 5 in 1 weather station.	HOBO® U30-NRC Station Starter System	Oregon WMR300A Ultra-Precision Professional Weather System	Prodata Systems: Davis Vantage Vue Weather Station
Ability to add sensors	NO	YES	YES	NO
Solar incorporation	NO	YES	YES	NO
Wireless sensors	NO	NO	YES	YES
Price	£175	£475	£299	£599

3. sensor selection.

For the measurement requirements of this assignment several different sensor types were needed. Following are comparison charts of some of the different sensors reviewed and the justifications for the choices made will be given for each of the sensor types.

3.1 Temperature and humidity sensor.

The maximum and minimum operating temperature of the sensor required for this assignment were 50 degrees c and -40 degrees c. There were several other parameters taken in to consideration when deciding which sensor was most suitable for this design. The following chart compares several different sensor types based on these parameters and a justification of the one chosen is provided.

					
	TE Connectivity HPP809A031, Temperature & Humidity Sensor	T9602-3-A-1 - HUMIDITY/TEMP SENSOR	HM1520LF - Temperature & Humidity Sensor	Sensirion SHT75, Temperature & Humidity Sensor	T9602-5-D - HUMIDITY/TEMP SENSOR
Operating voltage.	3-10v DC	3v DC	4.75–5.25v DC	2.4 to 5.5v DC	5v DC
Max temp.	85°C	50°C	60°C	128°C	50°C
Min temp.	-40°C	0°C	-40°C	-40°C	-40°C
Sensor Output.	Analogue 0-5v DC	Analogue 0-3v DC	Analogue 0-5v DC	Digital	Digital- I ² C Analogue PDM
Price	£56.52	£72.80	£100.53	£24.84	£74.83

The final decision of a temperature and humidity sensor was made based on several parameters, operating voltage, temperature range, output type and price. The choice made was the T9602-5-D - HUMIDITY/TEMP SENSOR found at RS online. This sensor was chosen because it satisfied the temperature range required for the assignment, the operating voltage was suitable for interfacing with a micro controller, its output is I²C interface, it was a reasonably priced sensor and it has an environmental rating of IP67[5].

3.2 wind speed and direction.

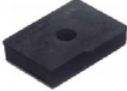
For the wind speed and direction many different sensors were found. Some were 2 individual sensors, some were both an anemometer and weather vane combined as 1 sensor and others were ultrasonic. Following is a comparison chart of some of those sensors and their specifications as well as the sensor selected for the design and the reasons for the choice made.

				
	Young/Cambell 03002 Wind Sentry Anemometer and Vane	WindSonic Ultrasonic Wind Sensor	AliExpress wind speed/direction sensors.	YOUNG 85000 Ultrasonic Anemometer
Operating voltage	Max 15v DC.	5-30v DC.	5v DC x 2	9 – 16v DC
Sensor Output	Speed- AC sine. Dir- DC voltage.	Analogue RS232.	Analogue 0 – 5v DC x 2	Analogue RS232.
Speed/ direction	Both.	Both.	Both, 2 separate sensors	Both.
Price	£713.71	Approx. £600	£ 78.15	£1169.36

The final choice of sensors for the wind speed and direction was the generic anemometer and wind vane from AliExpress. The main reason for this decision was the price, while researching sensors the prices of all found were extremely high as can be seen in the above table were as the ones chosen could be purchased together at a significantly lower cost. In addition, it was decided that the 0 – 5v analogue outputs of the sensors could be interpreted through software[6].

3.3 air borne particle sensor.

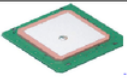
When choosing an air borne particle (dust) sensor it was realized that as well as the sensor itself, a fan would be needed in order to pass the air through the sensors detection area. The following chart compares some of the sensors researched and the one chosen for this design is identified and justified.

				
	HPM SERIES PM2.5 Particle Sensor	sharp GP2Y1010AU0F Particle sensor	Telaire SMART Dust Sensor SM-PWM-01C	Sharp DN7C3CA006 IR Dust Sensor
Operating voltage.	5v DC	4.5 to 5.5v DC	5v DC	Sensor-5v DC Fan-5v DC
Sensor Output.	UART	Analogue voltage	PWM	Analogue Voltage
Operating principle.	Laser scattering	Infrared	IR LED	Infrared
Price	£19.64	£9.13	£11.04	£37.00

The decision was made to use the Sharp DN7C3CA006 sensor from Digi-Key. Although it is the more expensive of the above selection it was chosen because of the analogue voltage output and the fact that it has a built-in fan that is powered independently from the sensor. This is advantageous because it allows for the fan to be turned off when not taking a reading, greatly reducing the overall current consumption of the design[7]. This sensor is a chassis mount design and will be attached to the bottom of the system casing allowing for a good amount of air flow to get to the sensor while protecting it from rain.

3.4 GPS sensor

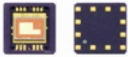
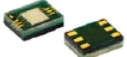
This design specification calls for a GPS module to be included, GPS has in recent years become a very common place feature of many mobile devices. Because of this increase in usage the availability has risen and the price of modules has decreased dramatically. Following is a brief comparison of some of the units reviewed and a description of the one selected for this design.

				
	RF Solutions GPS-622F GPS Receiver	RF Solutions GPS-330R GPS Receiver	ADAFRUIT INDUSTRIES 746 GPS Module	Quectel L86- M33 GPS Receiver
No. of channels	65	16	66	33 (tracking) 99 (acquisition)
Interface	UART	UART	UART	UART
Tracking sensitivity	-161dBm	-140dBm	-165dBm	-165dBm
price	£32.43	£32.51	£26.59	£10.25

When deciding on which GPS module to use there were not many variables other than price to take in to consideration. As the weather logging system, when in use will be stationary, only one reading will need to be taken at the start of the monitoring period. Because of the relative similarity between modules the choice was made based on price, the cheapest being the Quectel L86-M33 GPS Receiver from RS online. This module has a built in patch antenna, is extremely small and has a low power consumption level[8].

3.5 UV level sensor

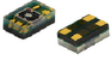
The ability to monitor UV levels was part of the specification for this design. When researching possible sensors, it was discovered that the majority of sensors available were on their own breakout board making installation easier. The following chart compares some of the sensors reviewed and their main characteristics.

				
	Rohm ML8511 UV sensor	Vishay VEML6070, UV Light Sensor	Adafruit UV Light Sensor Breakout - GUVVA-S12SD	Adafruit SI1145 UV Index / IR / Visible Light Sensor
Operating voltage.	3.3v	2.7 – 5.5v	2.7 – 5.5v	3 – 5v
Output Signal.	Analogue voltage.	I ² C	Analogue voltage.	I ² C
Dimensions (mm).	4.0 x 3.7 x 0.73	2.35 x 1.8 x 1	10 x 19 x 2	20 x 18 x 2
Price.	£3.25	£1.09	£4.80	£7.30

The sensor chosen for this design was the Vishay VEML6070 UV light sensor[9]. After comparing the specifications of several sensors, it was decided that this one satisfied the requirements of the design, was significantly cheaper and the I²C interface means less I/O pins are needed on the microcontroller.

3.6 Sun light brightness sensor.

There are many different types of sensor that can be used to measure sunlight brightness levels. In the following table, several of the sensors that were considered for this design are displayed and some of their specifications have been noted.

				
	ams TCS3200D Colour & light Sensor	Maxim MAX3806GTC+, Colour & Light Sensor	Broadcom APDS- 9309, Light Sensor	Vishay VEML6075, Light Sensor
Operating voltage.	2.7 – 5.5v	5v	2.4 – 3v	1.7 – 3.6v
Sensor Type.	Colour light to frequency.	Light to Voltage.	Light intensity to digital signal.	UV light Sensor
Interface.	I ² C	Analogue Voltage.	I ² C	I ² C
Price.	£4.06	£4.92	£1.29	£1.73

Although there are many different sensors that were reviewed and that could have been used for this design, it was decided that a simple generic Light Dependant Resistor (LDR) could be used. This component can be purchased from RS online for as little as 5p [10] and the light intensity can be measured as a varying voltage.

4. Microcontroller selection.

Because the UV and the temperature and humidity sensors both need an I²C interface, that was the first parameter addressed when choosing a microcontroller. The ability to interface an SD card to store the recorded data and a USB port for PC connection were then realised and included in the parametric search on the Microchip website. The microcontroller chosen was the PIC16F1508, a 20 pin 8 bit MCU [11]. As the I²C uses the data and clock pins RA0 and RA1, pins RC0 and RC1 were reassigned for the SD card interface.

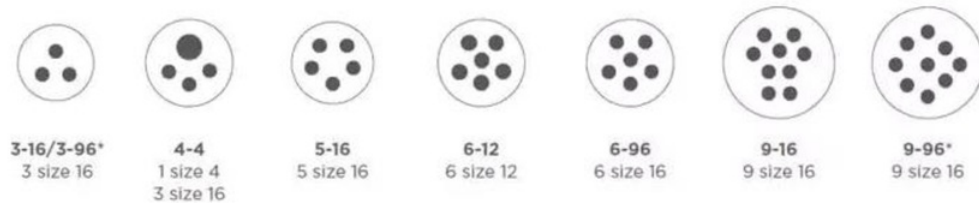
5. Battery and connector selection.

The specification for this assignment states that the system should be able to take measurements and record the data for a period of 7 days. To calculate the size of the battery needed the current drain of each of the sensors and the MCU needed to be calculated.

Temp/hum. Sensor = 75 μ A	UV sensor = 250 μ A
Wind speed sensor = 20 mA	GPS sensor = 23 mA
Wind dir. sensor = 20 mA	PIC = 30 μ A
Particle sensor = 20 mA	<u>total = approx. 180 mA</u>
Fan = 60 mA	
LDR = 25 mA	

For the system to operate for the specified time frame for the assignment, the battery would need to be a minimum of 12v 30AH. Chosen for this was a 12 v 110AH lead acid battery[12].

Only 4 of the sensors used in this design need external connectors as the rest are hardwired to the pcb. For these sensors DEUTSCH HD Harsh Environment Connectors were chosen. These connectors have an IP 68 environmental rating making them suitable for the intended outdoor use. They also come in a selection of pin configurations allowing for different sensors to have different connectors.



6. non-volatile memory storage.

The size of the memory needed is dependent on the frequency of each reading taken from each of the sensors.

- GPS – one reading per 7 days.
- Temperature – one reading every 2 minutes.
- Humidity – one reading every 2 minutes.
- Wind speed – one reading every 10 seconds.
- Wind direction – one reading every 10 seconds.
- Dust particles – one reading every minute.
- Brightness – one reading every minute.
- UV level – one reading every minute.

The calculation of total memory space needed is as follows:

GPS = 2B x 7 days	= <u>2 B</u>
Temp = 2 B (every 2 min) = 120 B per hour x 24 hours = 2880 x 7 days	= <u>20160 B</u>
Humidity = 2 B (every 2 min) = 120 B per hour x 24 hours = 2880 x 7 days	= <u>20160 B</u>
Wind speed = 2 B (every 10 sec) = 720 B per hour x 24 hours = 17280 x 7 days	= <u>120960 B</u>
Wind direction = 2 B (every 10 sec) = 720 B per hour x 24 hours = 17280 x 7 days	= <u>120960 B</u>
Dust particles = 2B (every minute) = 120 B per hour x 24 hours = 2880 x 7 days	= <u>20160 B</u>
Brightness = 2B (every minute) = 120 B per hour x 24 hours = 2880 x 7 days	= <u>20160 B</u>
UV level = 2B (every minute) = 120 B per hour x 24 hours = 2880 x 7 days	= <u>20160 B</u>
<u>Total</u>	= <u>325 Kb</u>

Using a 1 Gb SD card will more than adequate for the requirements of this assignment.

7. additional design specifications and costing.

For this type of monitoring system, as it is designed to work outside in varying weather conditions a strong weather proof casing is required. The case needs to be big enough to hold the battery as well as the PCB an approximate size would be 350mm L x 300mm W x 220mm D. It would also need a transparent lid so that the UV and brightness sensors can operate correctly and stabilizing legs to be added in order to raise the case off the ground so that the particle sensor can be mounted on the bottom of the case. An example of the type of case that would be suitable is Peli 1610 protective case but with some adjustments.

The approximate costing of this design is as follows:

Temp/humid sensor	£74.83
Wind sensors	£78.15
Particle sensor	£37.00
LDR	£00.05
GPS module	£10.25
UV sensor	£01.09
PCB	£30.00
Case	£200.00
Battery	£150
SD card	£05.00
PIC and components	£05.00
TOTAL	£531.37

7. circuit and PCB diagrams.

The following diagrams are of the completed schematic on Proteus and the PCB design from easy PC.

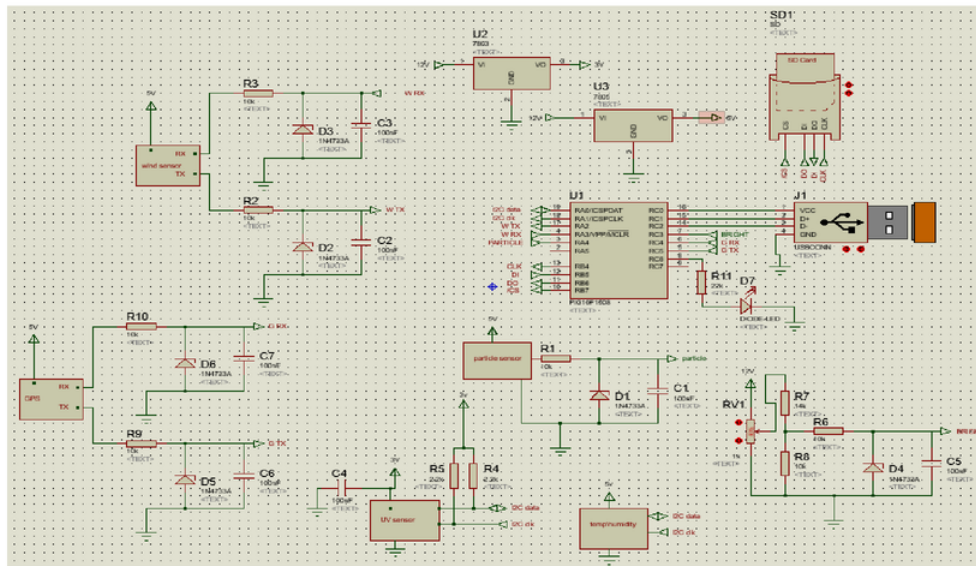


Diagram 1. Proteus schematic.

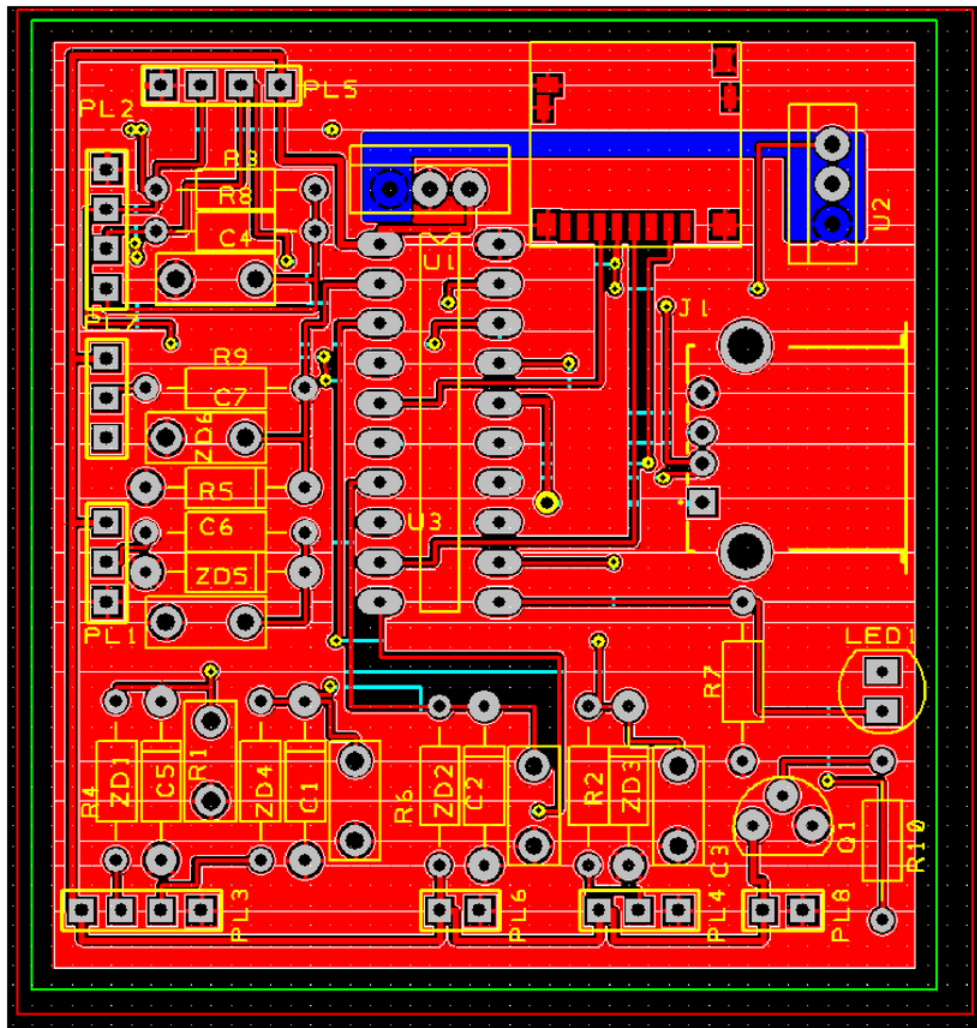


Diagram 2. Full PCB design.

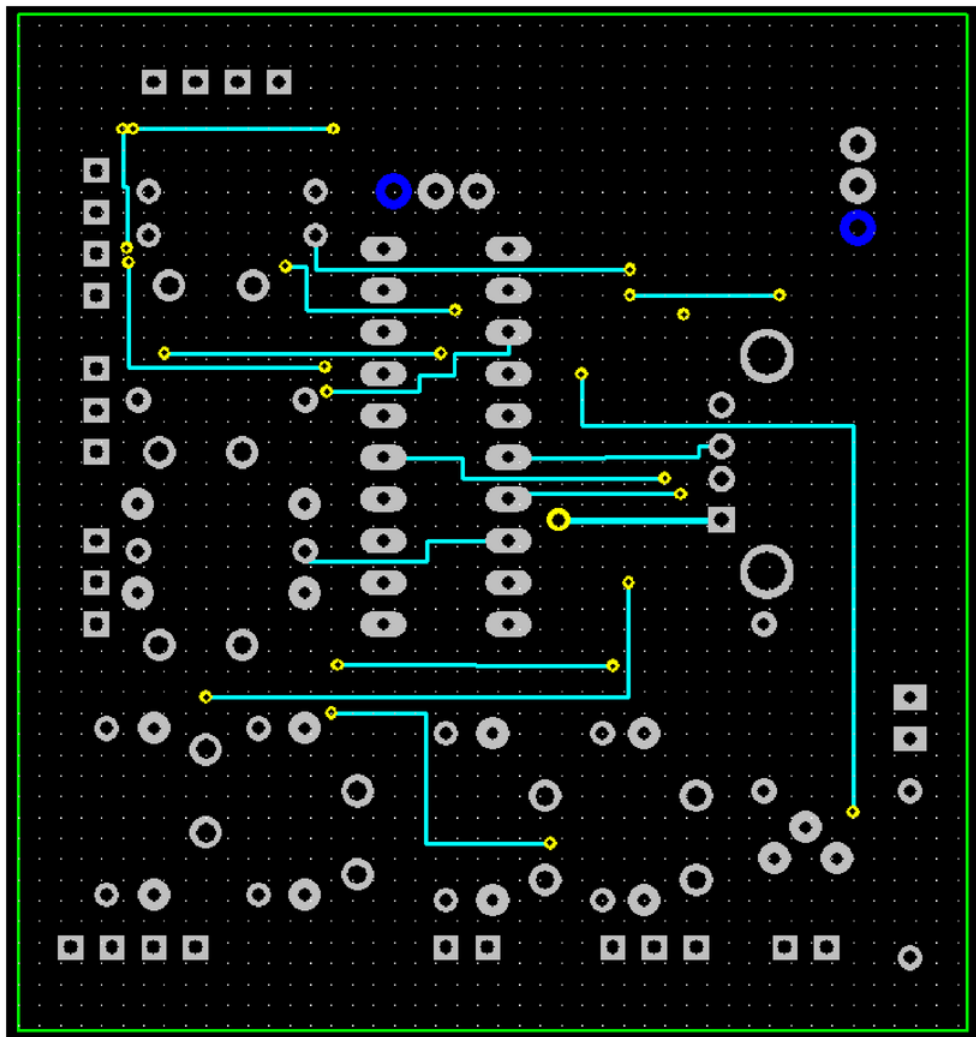


Diagram 3. Bottom layer PCB.

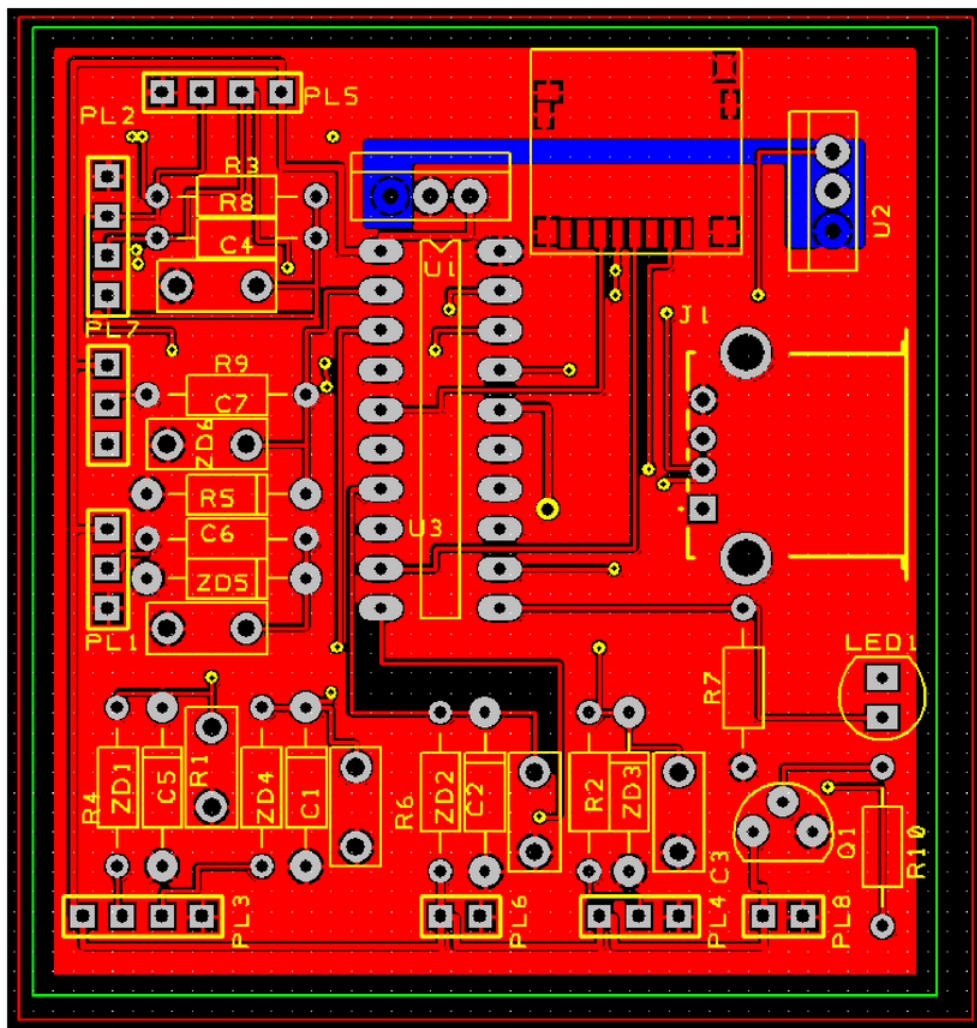


Diagram 4. Top layer PCB.

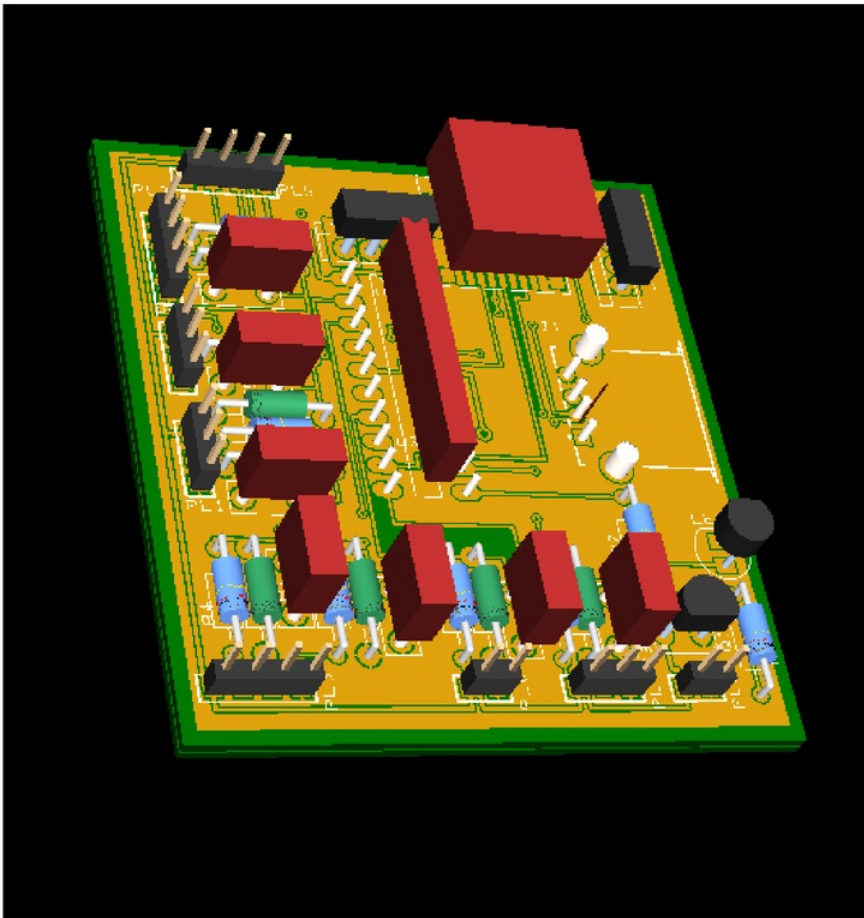


Diagram 5. 3D PCB.

8. Basic software structure diagram.



9. conclusion and future work.

When the PCB design was finished all checks were performed and after several attempts all the errors were corrected.

There are several ways in which this design could be improved. In order to reduce battery consumption transistors could be used to allow the microcontroller to turn off any sensors that are not in use, cheaper sensors could potentially be found and used and if this design was to be mass produced creating a completely custom case could significantly reduce the cost of production. Also the incorporation of some type of wireless transmitters to send the acquired data to a receiving terminal would improve the overall design

10. References.

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- [9] "VEML6070 | Vishay VEML6070, UV Light Sensor, Solar UV Light Intensity to Digital Data 355 nm I2C 2.7 → 5.5 V 6-Pin OPLGA | Vishay." [Online]. Available: <https://uk.rs-online.com/web/p/colour-light-sensors/1226789/>. [Accessed: 06-Jan-2018].
- [10] "NSL-19M51 | Luna Optoelectronics NSL-19M51 LDR (Light Dependent Resistor) 20 kΩ Light, 20MΩ Dark, 2-Pin TO-18 | Luna Optoelectronics." [Online]. Available: <https://uk.rs-online.com/web/p/ldr-light-dependent-resistors/9146710/>. [Accessed: 06-Jan-2018].
- [11] "PIC16F1508 - Microcontrollers and Processors." [Online]. Available: <http://www.microchip.com/wwwproducts/en/PIC16F1508>. [Accessed: 06-Jan-2018].

- [12] "Universal 12v 110AH Deep Cycle AGM Battery UB121100." [Online]. Available: https://www.batterystuff.com/batteries/ups-telecom/universal-12v-110-ah-deep-cycle-sealed-agm-battery-ub121100-d5751.html#WayPointInformation0011_10142_10107,searchweb201603_1,ppcSwitch_7&algo_expid=51de5395-08bf-49e7-9e64-0a765109e751-14&algo_pvid=51de53. [Accessed: 06-Jan-2018].

FINAL GRADE

GENERAL COMMENTS

Instructor

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DANIEL LENNON**53.30****RESEARCH-INFORMED LITERATURE**

Resonable literature review. The table of the devices is good but would have been improved with thumbnail images of the devices in the table. 60%

9**KNOWLEDGE AND UNDERSTANDING**

Reasonable overall schematic design but a few problems can be seen. This chip does is not USB compatible so it needs to be connected to a rs232 to usb conversion chip something like an FTDI device. The fan does not have power connected to it but diectly to the collector of Q1. The LDR has no way of producing an output as the is no potential divider resistor in situ. The outputs of the particle sensor, the ldr circuit the wind direction and the wind speed sensors have 10k serial resistors which would invalidate any attempt by the zener to clamp voltage, additionally the led has a series resistor of 10k which would limit the current below its working range. Nice pcb layout. 50%

17.5**ANALYSIS**

Poor selection of microcontroller as it does not have USB. Good selection of sensors with a nicely

15.6

laid out table showing a number of sensors to be chosen from with an image of each allowing the user to quickly absorb the information. No case selection made. No selection of connectors. 52%

PRACTICAL APPLICATION AND DEP.



Costings put forward as a table with price but without supplier of component and a lot lacking detail. Fair attempt at future enhancements. 50%

5

SKILLS FOR PROFESSIONAL PRAC.



The report is reasonably presented with nicely tabled data which could have been improved with more images/illustrations, a flowchart is provided. Reasonable selection of references. 62%

6.2