

Weather Data Logger

by Glen Joseph Henley

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DESIGN OF A DATA ACQUISITION SYSTEM



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Introduction

This report will demonstrate the procedures taken into designing a data acquisition system. The System is to be a weather system, this system must also be portable re-usable and adaptable to a wide range of environments. The system requirements are to measure:

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

Connectors will also be research to pair the sensors with the microcontroller.

The system must record this data over a 7 day period to non-volatile memory which can be externally read and cleared when connected to a computer via USB and to be battery powered.

Included will be research of existing weather systems to gain information on what features they possess and parameters that manufacturing companies use.

The thought process of the selection of each sensor is included paying fine detail to the parameters in order to meet the report specification, other parameters have been considered for easy installation/interpretation of sensor signals.

The design itself will be created on easy PC providing PCB layouts, schematic diagrams will be created using proteus.

1 Literature Review

1.1 Weather Transmitter WXT530 Series



Features:

- Right parameter combination
- Easy to use and integrate
- Weather parameter hub
- Analogue sensors can be added
- Compact, light weight
- Low power consumption
- mA output suitable for industrial applications
- Cost effective
- Measures rainfall, windspeed, wind direction, pressure, temperature and relative humidity.

[1]

The weather transmitter wxt530 is a combination of multiple sensors that can be connected up to a datalogger as it provides outputs such as SDI-12, RS-232, RS-485 and RS-422. This particular product does not include a datalogger but has been selected as it contains parameter information that can be useful when selecting sensors in relation to the design specification.

1.2 H21 – USB Hobo Micro Weather Station



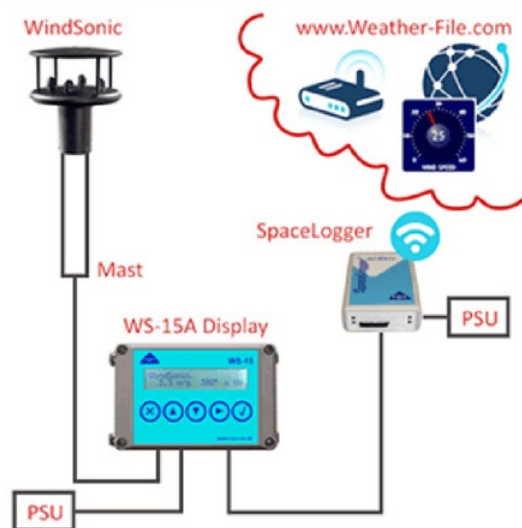
Features:

- Compact size for easy deployment
- Weatherproof IP66 enclosure for harsh environments
- Direct USB offload, no need for an adaptor
- Hinged door and integrated mounting tabs
- Runs for up to a year on four standard AA batteries
- Compatible with HOBOWare software
- With 5 smart sensors with Ethernet connections it can measure wind speed, wind direction, temperature, rainfall, pressure, soil moisture and solar radiation.

[2]

The USB hobo micro weather station differs from the WTX350 as it demonstrates only the data logger. It provides 5 Ethernet ports that allow smart sensors to be connected directly. This particular product has been chosen as it demonstrates USB connectivity, casing properties and parameter information that may be useful when designing the weather system datalogger.

1.3 FlexiMet Wind 3 System



Features:

- High Quality Wind Monitoring System
- Easy to Install
- Wi-Fi Connectivity
- No moving parts, requires virtually no maintenance
- Complete 0 to 360° operation with no dead band
- Requires no calibration and is drop tested from 1m height
- Includes real-time display
- Measures wind speed and direction

[3]

The FlexiMet wind system provides both sensor and logger with an addition of a screen. This has been selected as it provides data storage in form of an SD card and would be informative to see

what connectors are being used to connect the sensor to the screen, power supply and the logger which is asked for in the design specification (exclusion of a display).

1.4 WxPRO



Features:

- Full-featured weather station for the budget-conscious researcher
- Defensible data obtainable with accurate instruments
- Remote system deployment with low-power design
- Remote connection with many communications options supported
- Customizable system for specific application needs
- Measures windspeed, wind direction, temperature, relative humidity, pressure, precipitation and solar radiation.

[4]

The WxPRO has been selected as it provides nearly everything that is required by the design brief, from sensors, battery requirement, loggers, connectors and mounting equipment (casing). This source is very informative providing datasheets for all the listed parameters.

1.5 Comparison Table

Weather Data System	Weather Transmitter WXT530 Series	H21 – USB Hobo Micro Weather Station	FlexiMet Wind 3 System	WxPRO
				

Inputs	Measures rainfall, windspeed, wind direction, pressure, temperature, relative humidity.	5 Smart Sensors	Windspeed and Wind direction	Measures rainfall, windspeed, wind direction, pressure, temperature, relative humidity.
Input Ranges	Temperature: -52 to + 60 Humidity: 0 - 100 %RH Wind Speed: 0 -60 m/s (133mph) Wind Direction: 0-360 Deg	Dependant on smart sensors chosen	Wind Speed: 0 -60 m/s (133mph) Wind Direction: 0-360 Deg	Temperature: -40 to + 70 Humidity: 0 - 100 %RH Wind Speed: 0 -60 m/s (133mph) Wind Direction: 0-352 Deg
Input Voltage/Battery (Volts)	6-24	6	Windsonic Sensor: 12 Data Logger: 5	12 10 W Solar Panel
Output Type	SDI-12, RS-232, 485, 422	USB	Windsonic Sensor: RS-232 Datalogger: Wifi, SD Card, USB	Temp & Humidity: SDI-12 Windvane and Anemometer: Voltage Data Logger: Wifi, SD Card, USB
Power Consumption (Current)	3.5mA at 12VDC	N/A	Windsonic Sensor: 5.5mA @ 12v Data Logger: 200mA @ 5v	N/A (Broken Link)
Weight (kg)	N/A	0.4 (Inc PSU) (Inc Mounts)	1.85 (Ex PSU) (Ex Mounts)	4.7 (Inc PSU) (Ex Mounts)

Data has been extracted from the available datasheets that will aid the design of my own weather system data logger. However input ranges that measure pressure and rainfall have not been included as they do not meet design specification but could be included in the improvements section for the future as its popular within current weather systems.

- **Inputs**
Inputs is a parameter to be highlighted to see what data is measured when looking at current weather systems.
- **Input ranges**
It's important to get a rough unit measurement for each type of data input for when researching my own sensors to see if they're adequate for a current weather system.
- **Input Voltage/ Battery/Power Consumption**
As selecting a battery is within the design specification, it is important to see what input voltage and current consumption weather systems use in order to get a rough idea. As the

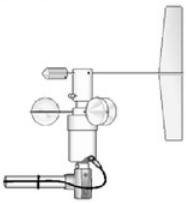
system needs to run for 7 days, mAH has to be calculated in order to choose an adequate battery.

- **Output Type**
Popular output types are SDI-12, RS-232 and voltage. Unfamiliar with RS-232 and SDI-12 further research is required to see the benefits of each. However voltage is an easy output type to work with and will be selected for easy understanding and simplicity.
- **Weight**
Weight is overlooked most of the time, however if the system needs to be portable and run off a DC supply, weight is important. A heavy system can deem importable.

2 Selection of Sensors

Research will now be conducted on sensors that are sufficient to measure the data as required in relation to the specification. Four sensor will be considered when selecting the final sensor to go forward to the final design with justification on why the chosen sensor has been selected.

2.1 Windspeed & Direction

Sensor Name	WMS-23	A-100L2 w/ W200P	WindSonic M	034B
				
Measurement Range (MPH)	0 - 100	0 - 168	0 - 134	0-167
Measurement Range (Degrees)	0 - 360	0 - 360	0 - 360	0-360
Supply Voltage (Voltage)	8 - 30	6.5 – 28 & 1 - 5	5 - 30	N/A
Output	4-20 mA & Pulsed Contact Closure	Pulse or Analogue 0-5v	RS232 or 0 - 5v	Pulsed Contact Closure
Current Consumption	N/A	2mA	5.5mA - 40mA	<1mA
Selected Sensor (*)		*		

As the star indicated, the A-100L2 with the W200P is the selected sensor. The reason being:

- Wide range of wind speed
- Has the full 360 degree potentiometer readings
- Has a simple analogue voltage output between 0-5 volts
- Adequate input voltage range
- Low current consumption

WMS-23

This sensor did not appeal to me as it did not match the ranges of the other three sensors in terms of measuring windspeed as it could only measure up to 100mph. Another reason for not selecting this sensor is that it uses pulsed contact closure as an output therefore being mechanical and could be a liability if the sensor is not maintained regularly.

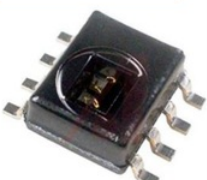
Windsonic M

The only parameter that stopped me from using the Windsonic M is the output it delivers, rs232 give an output of +-12v which is not suitable for a microcontroller. The sensor did have another output option that being a voltage output between 0-5 volts, however the datasheet starts that if this output is to be used that the current drawn from the sensor will be 40mA, this is not ideal as more current drawn the bigger the battery needed.

034B

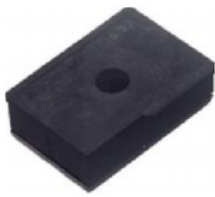
The 034B is almost perfect apart from the pulsed contact closure, therefore once again requiring regular maintenance. My understanding of how it delivered a voltage output using the excitation of a data logger as explained in the datasheets is minimal. This sensor would've been chosen if my understanding of the product was better.

2.2 Temperature & Humidity

Sensor Name	HDC1000YPAT	Si7021-A20-IM	HIH8121-021-001S	HIH9130-021-001S
				
Relative Humidity (%)	0-100	0-100	0-100	0-100
Temperature Range (Degrees C)	-40 to +125	-40 to +125	-40 to +125	-40 to +125
Operating Voltage (V)	2.7 - 5.5	1.9 - 3.6	2.3 - 5.5	2.3 - 5.5
Interface Type	I2C	I2C	I2C	I2C
Package Type	BGA	DFN	SIP	SOIC
Selected Sensor			*	

Looking at RH, temperature and operating voltage they all meet a suitable criteria, however looking at the images of the sensors there were packaging that was unfamiliar to me. The HDC1000YPAT and the Si7021-A20-IM have package types BGA and DFN which require special soldering techniques in order for them to be used, they also are very small in size. If the design specification required size a strict size PCB these two products may have been chosen. Leaving sensors HIH8121 and HIH9130 left to considered, the HIH8121 has been selected as it requires no external mount to be connected.

2.3 Air Borne Particle Count

	GP2Y1010AU0F	SM-PWM-01C	GP2Y1023AU0F	DN7C3CA007
Sensor Name				
Supply Voltage (Voltage)	-0.3 to +7	5	5	5
Output Type	Voltage	PWM	PWM	Voltage
Sensitivity	0.5/(0.1mg/m3)	n/a	1400µs/(0.1mg/m3)	n/a
Current Drawn	11mA	90mA	15ma	20ma
Selected Sensor (*)	*			

As the star indicated, the GP2Y1010AU0F is the selected sensor. The reason being:

- Very informative datasheet
- Has a simple analogue voltage output between 0-5 volts
- Adequate input voltage range
- Lowest current consumption of all considered devices

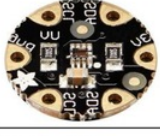
2.4 Sunlight Brightness

	NSL 4962	NORPS12	TSL261RD	TSL250R-LF
Sensor Name				
Input Voltage (V)	0-320	0-250	6	2.7-5.5
Operating Temperature (Degrees C)	-60 to +75	-60 to +76	-25 to +85	0 to +70
Output	Resistance	Resistance	Voltage	Voltage
Casing	Hermetic	Enclosed Plastic Casing	IC	IC
Current Drawn	N/A	N/A	1.1mA	1.7mA
Selected Sensor (*)			*	

As the star indicated, the TSL261RD is the selected sensor. The reason being:

- Very informative datasheet
- Has a simple analogue voltage output between 0-5 volts
- Adequate input voltage range
- Lowest current consumption

2.5 Ultraviolet Levels

	Adafruit 1981	UV-B Sensor (SKU 430)	Sglux UV-Air	ML8511
Device Name				
Input Voltage (V)	1.71 - 3.6	0-5	7-24	-0.3-4.6
Operating Temperature (Degrees C)	-40 to +85	-60 to +76	-40 to +80	-20 to +70
UV Range (nM)	550-1000	320 - 290	N/A	280 -390
Output	IC2	Voltage	Voltage	Voltage
Casing	N/A	Enclosed Plastic Casing	IC	N/A
Current Drawn	5.5mA	1mA	<30mA	1.3mA
Selected Sensor (*)		*		

As the star indicated, the UV-B SKU 430 is the selected sensor. The reason being:

- Very informative datasheet
- Has a simple analogue voltage output between 0-5 volts
- Adequate input voltage range
- Lowest current consumption

2.6 GPS

Device Name	GPS TTL Mini	GPS16X-HVS	Microstack GPS	Adafruit GPS
				
Supply Voltage (V)	3.3 - 5	8 - 40	2.8 - 4.3	3.3 - 5
Antenna	Y	Y	Y	N
Output Type	UART	RS232, TTL	SPI	PPS
Current Drawn	55mA	65mA @ 12VDC	25mA	20mA
Selected Sensor (*)	*			

As the star indicated, the UV-B SKU 430 is the selected sensor. The reason being:

- Very informative datasheet
- Adequate input voltage range
- Antenna is included
- UART can easily be configured in PIC software

2.7 Final Sensors

Device Name	GPS TTL Mini	A-100L2 w/W200P	HIH8121-021-001S	GP2Y1010 AU0F	TSL261R D	UV-B Sensor (SKU 430)
Supply Voltage (V)	3.3 - 5	6.8 – 28 1 - 5	2.3 - 5.5	-0.3 to +7	6	0-5
Output Type	UART	Voltage	I2C	Voltage	Voltage	Voltage
Current Drawn	55mA	2mA	0.65mA	11mA	1.1mA	1mA
Cost (£)	12	1100	50.64	10	1.5	27.5

These are the final sensors chosen displaying simple information such as supply voltage, output type and current drawn. Looking at this table 6/7 sensors can be run of 5 volts excluding the anemometer that has a minimum of 6.8 volts, this can be run at 12 volts as it's a preferred value when selecting a battery. Cost has been included to satisfy the overall cost within the specification.

3 Selection of PIC

Considering a PIC can be difficult as there are many parameters, however looking at the specification we already have knowledge of necessary parameters. Theses parameters are:

- USB
- Minimum of 9 A/D channels
- UART (MicroSD compatibility)
- 8bit Microcontroller

Program memory and internal oscillation have also been inserted. Programmed memory that has been estimated at 4k, to be sure this number has been multiplied by 4 to be safe. Internal oscillation has also been selected to allow more space for the PCB when designing and also results in less additional circuitry.

After all these parameters have been inputted the selection tool has left me with 4 options as shown.

Total # of A/D channels	UART	CPU	Number of USB Modules	Program Memory Size (Kbytes)
0 3 4 5 8 9 10 11 12 14 15	[Reset] 0 1 2 3 5	[Reset] 8-bit AVR 8-bit PIC 8-bit PIC MCU	[Reset] 0 1	1.75 2 3.5 4 7 8 14 16 28

Product	Channels	Program Memory (kbytes)	UART	USB	RAM
PIC16F1459	9	14	1	1	1024
PIC18F13k50	9	8	1	1	512
PIC18F4k50	9	16	1	1	768
PIC18F24K50	14	16	1	1	2048

Selection of the PIC18F24K50 has been selected as it meets all of the specifications, the only other PIC to meet all desired parameters is the PIC18F4K50 how this hasn't been selected as it has less ram and only 9 A/D channels (14 allows more room for improvement and error). The current consumption for this pic is 25mA (not low power mode).

4 Battery

When selecting the battery we need to know two things:

- Current drawn from the circuit
- How long we need to run it for
- Max voltage of a particular sensor

Current drawn from the circuit is 72.75mA (This is the sum of the sensors and the micro controller).

The specification requires the weather system logger to run for a week. This is 168 hours.

Current drawn multiplied by the amount of hours needed to run = 11886mAH. Sources say that if it's a rechargeable battery divide this number by 0.7, this prevents the battery going to 0 charge and leaves 30 percent of the charge left, this allows more cycles of the battery. [5]

All sensors are run on 5 volts apart from the anemometer which has a minimum voltage of 6.8 and a max of 28 volts. It is safe to say we can run this sensor on 12 volts. A battery that supplies 12v with a mAH rating of minimum 17000.



The chosen battery weighs at 4.9 kg
Dimensions: 167mm x 181mm x 77 mm
£39.08

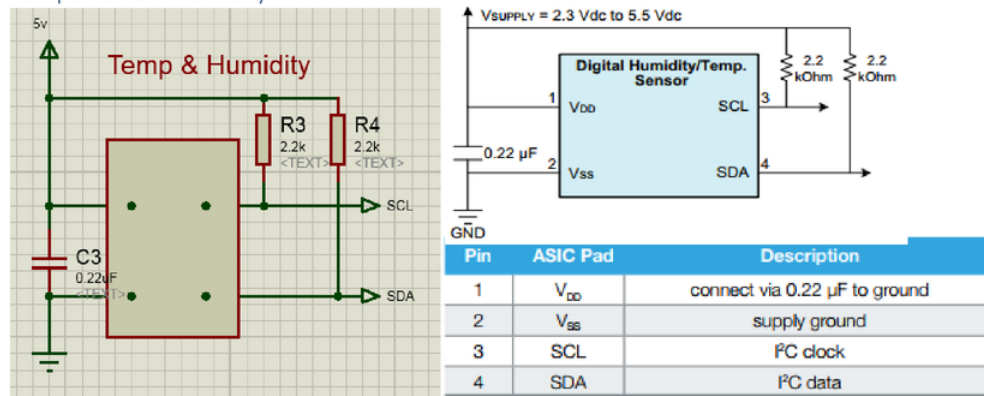
[6]

5 Proteus Design

The sensors, microcontroller and battery have been chosen we can move onto the designing stage.

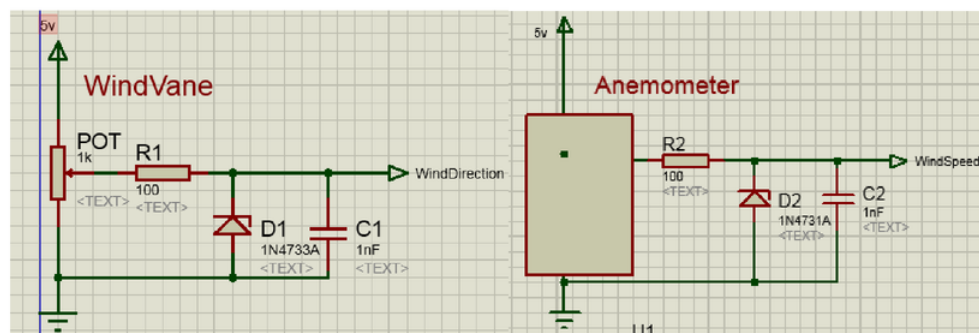
5.1 Sensors

Temperature + Humidity



For the temperature and the humidity digital sensor the Proteus design has been directly taken from the manufactures notes to satisfy the operation for I2C configuration. I2C serial configuration require two pull up resistors as shown in the design, one being the SCL being the clock and SDA being data.

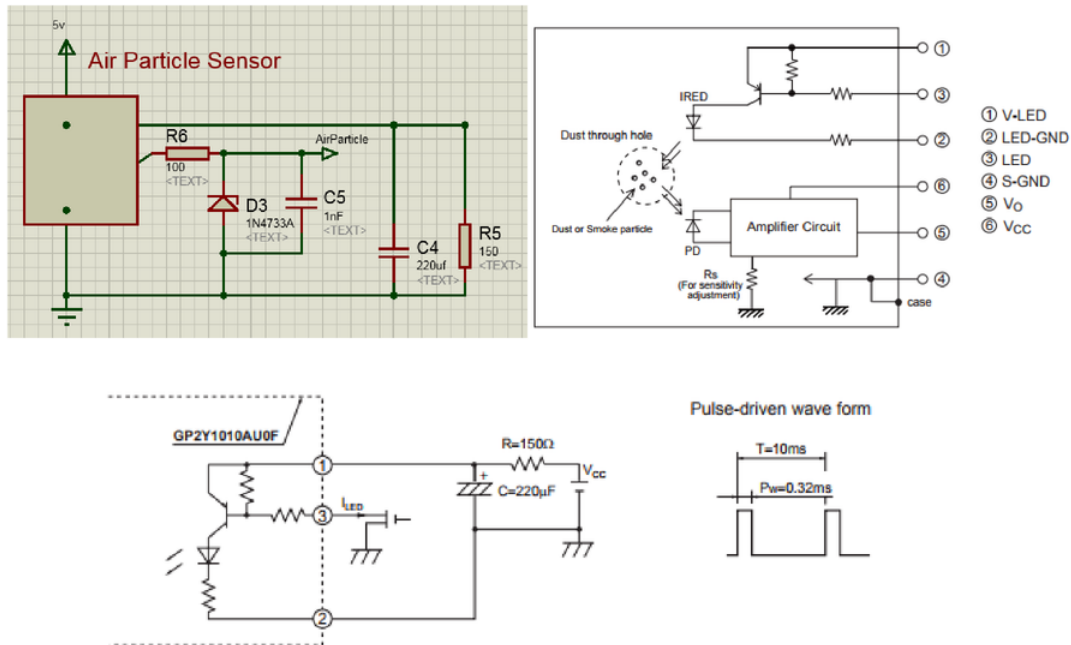
5.1.1 WindSpeed + Direction



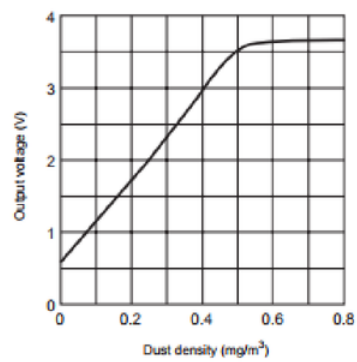
The windvane is a potentiometer that has a 1k nominal resistance and a recommended voltage supply between 1-5v. The additional circuitry caps the output voltage of the windvane to 5v ensuring that there is no damage to the microcontroller if there is a fault with this sensor. The datasheet allows for either a 5 wire operation or 3, a 3 wire operation has been chosen for simplicity and to allow more space on the board when designing the PCB. The anemometer requires a minimum a supply voltage of 6.8v (Diagram is showing 5v and this is a mistake, further design process has been

corrected and a 12v supply has been inserted). The anemometer provides an analogue output of 0-5v and additional circuitry has been designed to ensure it doesn't exceed this voltage.

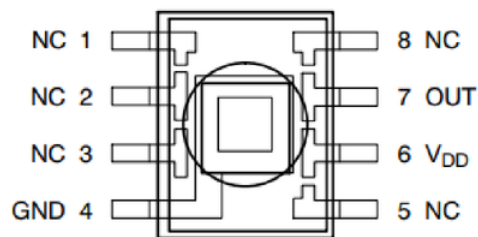
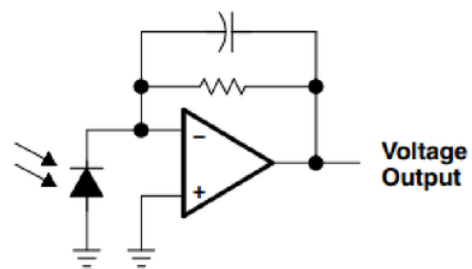
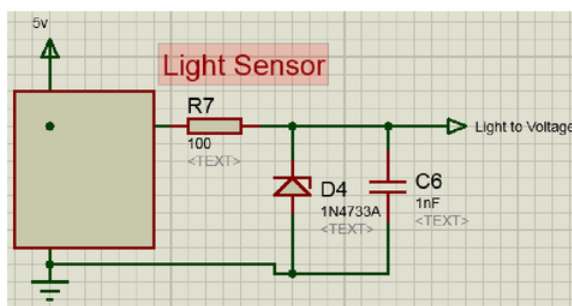
5.1.2 Air borne particle count



The air particle sensor has a max voltage supply of 7v, 5 has been chosen for easier design when creating the PCB using copper pours. The sensor consists of an IR sensor, a transmitter (IRED) and a receiver (PD). The IR sensor is pulse driven by C4 and R5 that allows the IR sensor to transmit every 10ms. The output of the sensor has a somewhat linear relationship with voltage up towards 0.5 mg/m³ as show below. Additional circuitry has been included to once again cap the output voltage to 5v to protect the microcontroller.

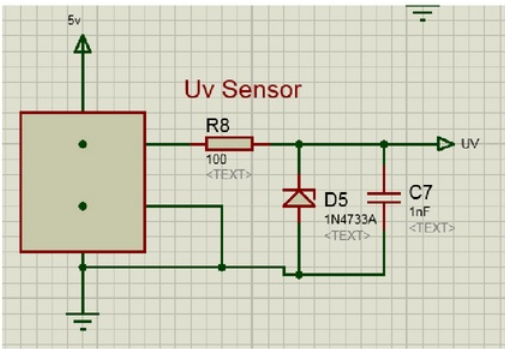


5.1.3 Sunlight Brightness



This digital light sensor is a photodiode with a transimpedance amplifier giving an analogue voltage output between 0-5v and is directly proportional to irradiance as shown below. The sensors max voltage is 6v and as the Proteus design shows, the sensor is being supplied by 5v which is sufficient for the sensors voltage supply. Additional circuitry has been added to ensure the output doesn't exceed 5v.

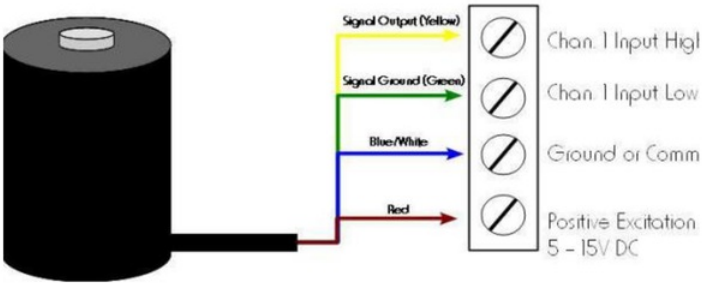
5.1.4 UV Levels



*5.15 volts for standard UV sensors

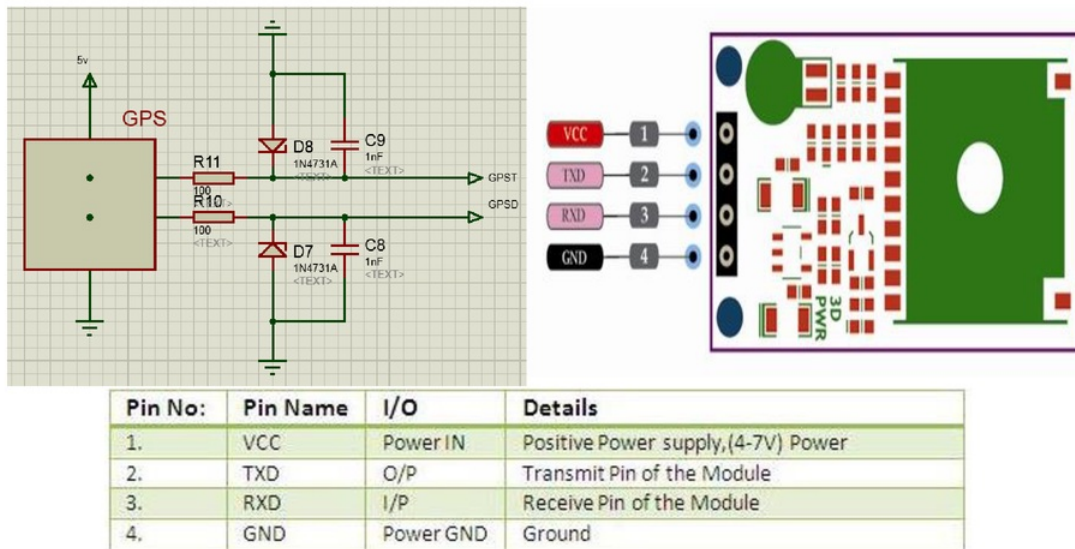
5.2.2 SKU 421 or 430 or 440 /1 or /SS2

Wire Colour	Function	Pin
Red	Positive Supply 5-15 volts*	Pin 1
-	-	Pin 2 (not used)
Green	Sensor Signal Ground	Pin 3
Yellow	Sensor Signal Positive Output	Pin 4
Blue + White	Power Supply Ground +cable screen + Sensor Body	Pin 5



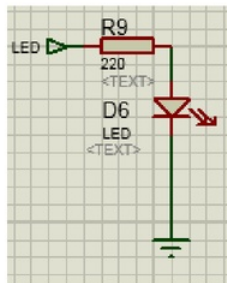
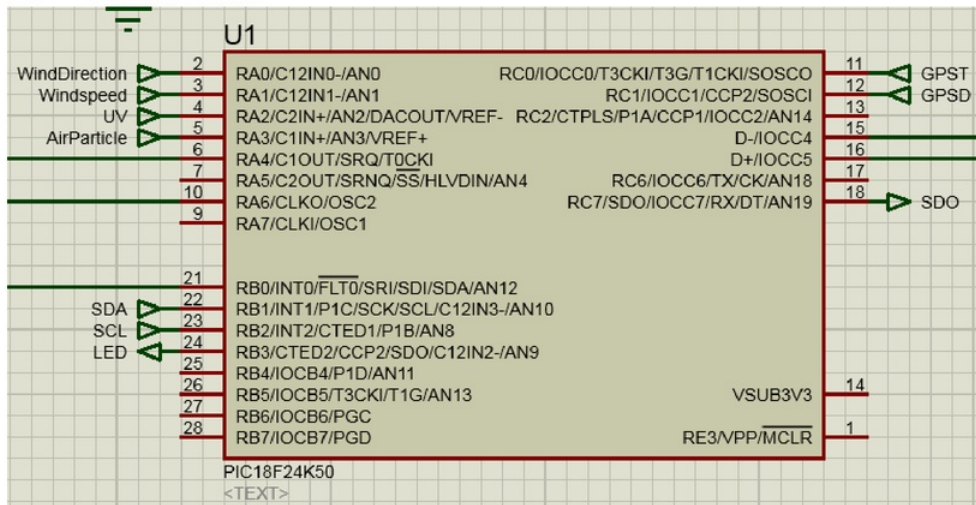
The max voltage this sensor require is 15v, however depending on what output voltage you desire the input must be at least 2v higher. The chosen input voltage is 5v as shown, therefore the output voltage will be between 0-3.

5.1.5 GPS Position



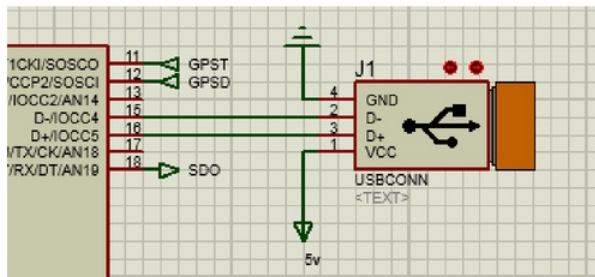
As shown in the table above the GPS module can be run off between 4 and 7 volts, 5v has been used for easier design purposes. The TXD pin is to be connected to the RX pin on the microcontroller and vice versa. Additional circuitry has been included to keep the data lines at 5 volts to ensure no damage to the microcontroller.

5.2 Microcontroller

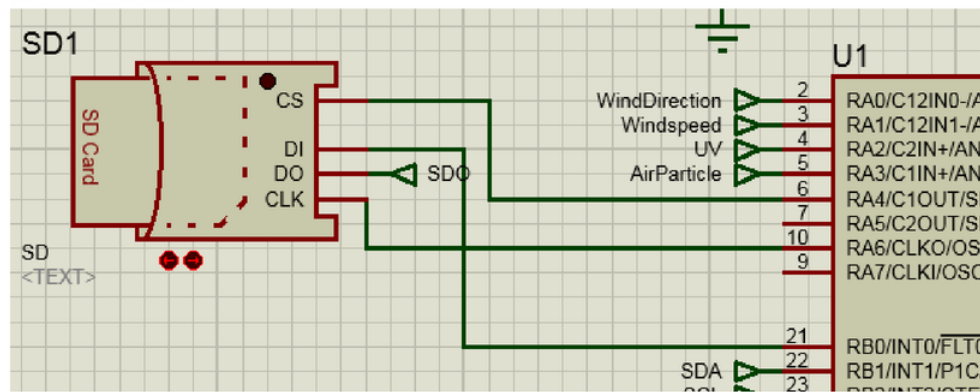


LED has been included to inform the user that the datalogger is running.

5.3 USB



5.4 MicroSD

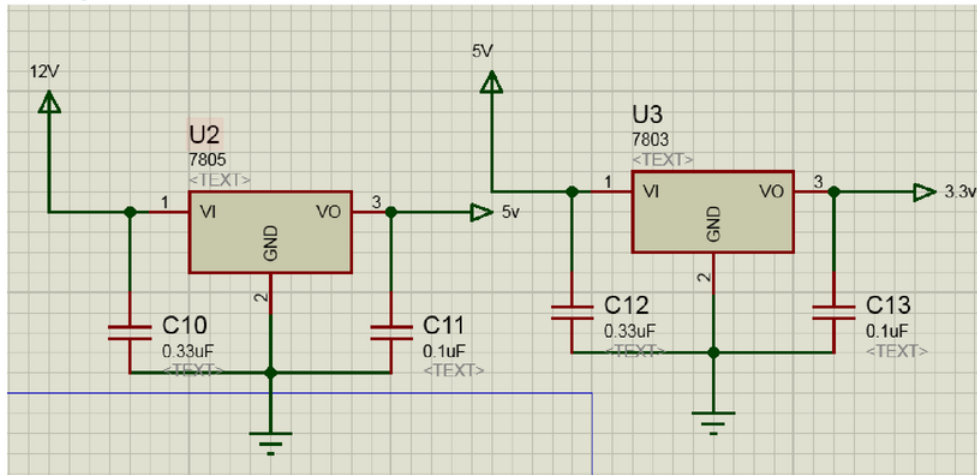


One of the specification asks to work out what size SD is required:

Data Type	Read Time Interval Seconds	Measurements per Second	Number of Measurements a Day	Number of Measurements in a Week	Reading Size (bits)	Amount of Data in a Week	Data per Second
Temperature	10	0.1	8640	60480	14	846720	1.4
Humidity	10	0.1	8640	60480	14	846720	1.4
Wind Speed	1	1	86400	604800	10	6048000	10
Wind Direction	1	1	86400	604800	10	6048000	10
Particle	60	0.01667	1440.288	10082.016	10	100820.16	0.1667
Sunlight	1	1	86400	604800	10	6048000	10
UV	1	1	86400	604800	10	6048000	10
GPS	once on start-up				10	10	0
					Total	25986270.16	42.9667
		Total Storage (MBytes)					
		3.24828377					

A 2 GB SD card should be plenty to store all of the data that is recorded.

5.5 Regulators

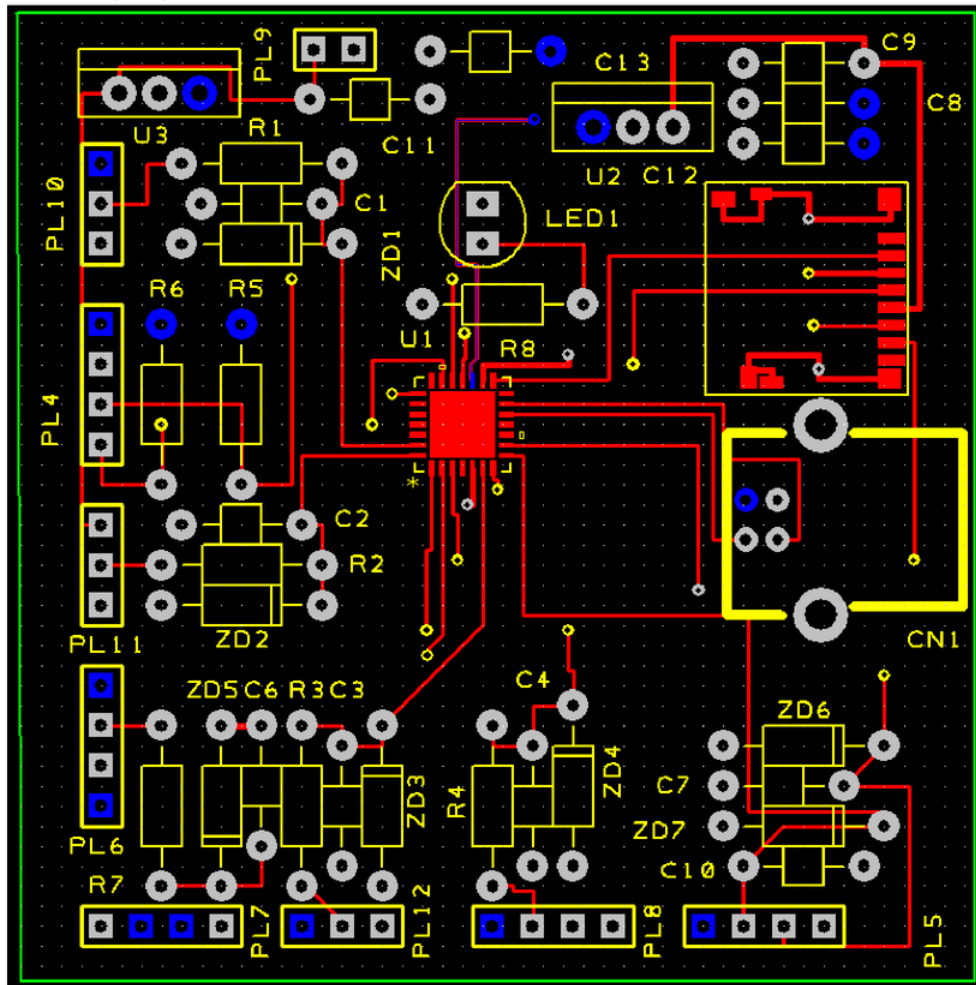


A 12 volt supply is fed into the input of a 7805 regulator and 7803 giving an output of 5 volts and 3.3 volts. (U3 is supplied by 5 volts in this image however it is not wise to feed a regulator an output from another regulator).

Now that the design process is ready we can now translate it to PCB using Easy PC.

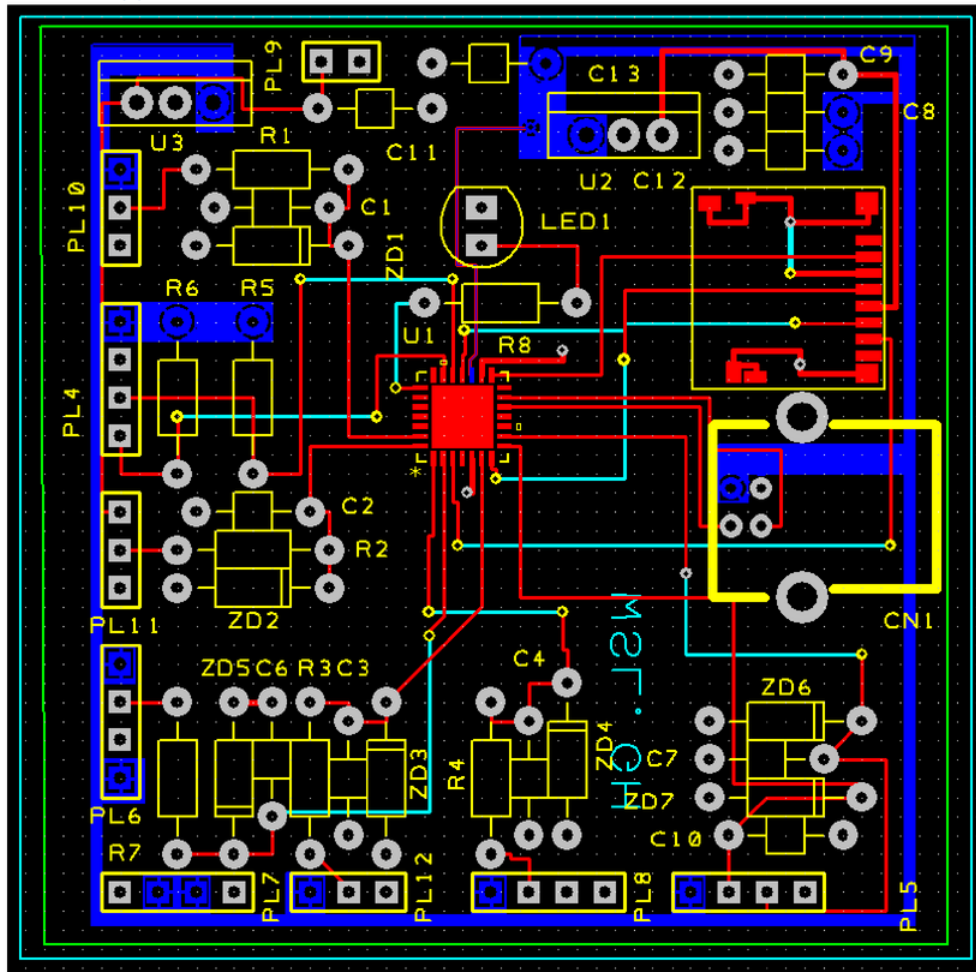
6 Easy PC PCB Design

6.1 Top Layer

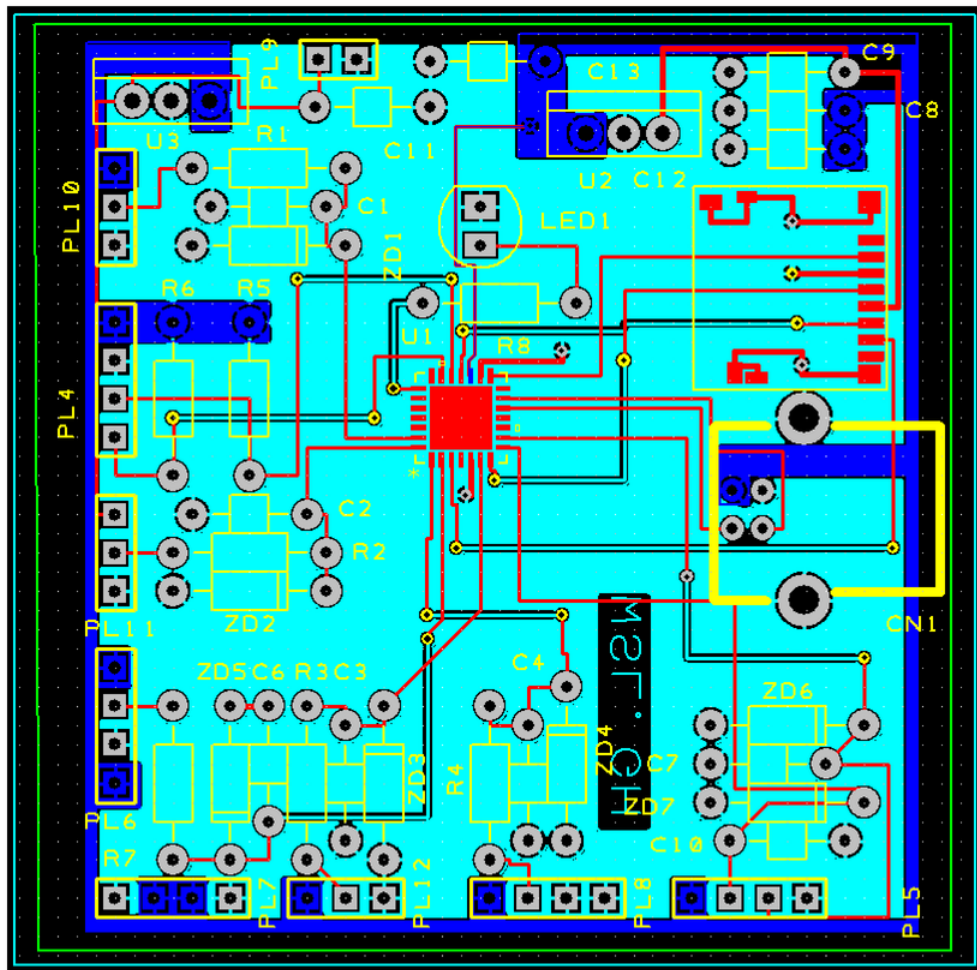


This is the top layer of the PCB show the connections, components, connectors and vias. Highlighted are the 5 volts connections that need to be connected using a copper pour.

6.3 Copper Pour

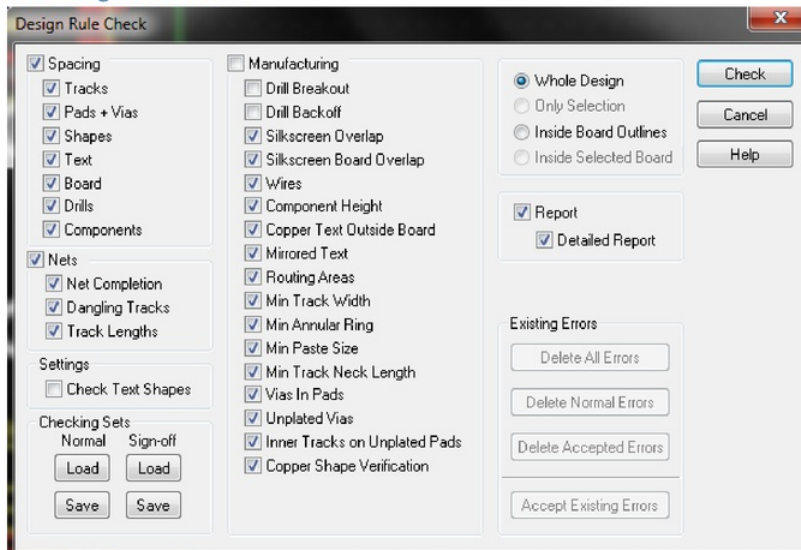


This is showing all the 5 volt connections being connected via copper pour. Next step is to add the 0V copper pour.

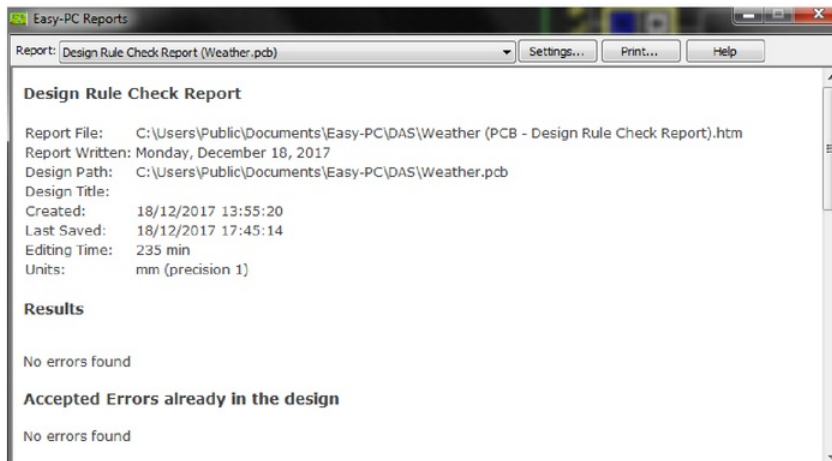


This is showing all the 0V connections being made via a 0V copper pour. Next step is to use rule design check to ensure there are no issues with the PCB design.

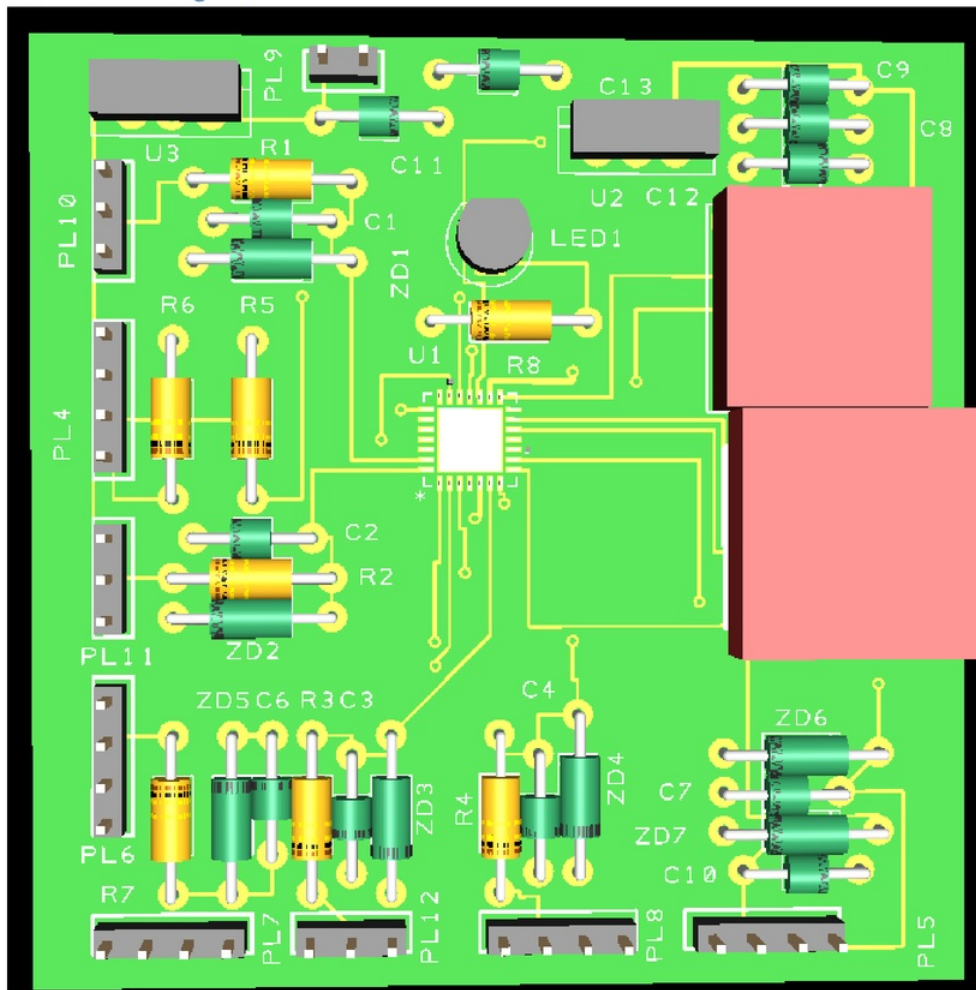
6.4 Design Rule Check

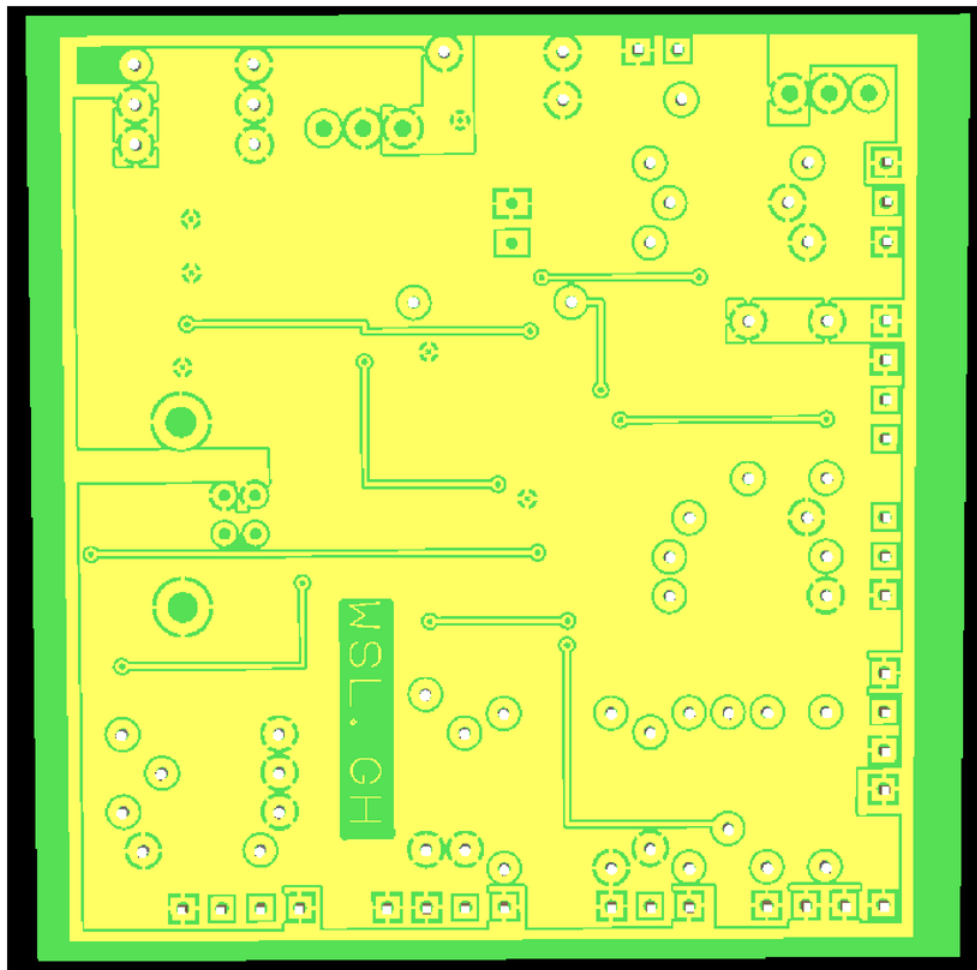


All boxes must be ticked excluding drill breakout and drill backoff. The result:



6.5 Final Design 3D





Cost

	Cost (£)
Sensors	1201.64
Battery	39.08
MicroSD	2.99
PCB	10
	1253.71

Cost of the equipment such as casing, mounts, connectors and small components have not been added. Equipment such as tripods glass casing to protect the sensors it would be wise to add another £500 to the total above as an estimates.

Improvement

Sensors

All sensors have a temperature operating range, the specification did not clarify what environments the weather system would operate in. The temperature sensor can record values down to -40 however some of the components won't operate at those temperatures. Future improvement may include a component heater or components that specialise in harsh environments.

The anemometer/wind vane size is not the smallest when looking at the datasheets and may be a pain to transport, selecting a smaller windvane/anemometer for future projects may satisfy the portable specification better.

An anemometer has an opportunity using wind as a source of energy, for future designs a sensor that can use this to its advantage to trickle charge back into the battery therefore reducing it in size.

PCB

When designing the PCB a lot of vias were used for connections, this increases the cost of the board. Using a different packaging microcontroller and recording the location of pin number before wiring it up would've made designing the PCB easier.

Battery

The current battery chosen is a decent weight, but can be made lighter. To do this using lower power mode for the IC may be an option, using minimum input voltage for the sensors is also an option therefore reducing the mAH consumed by the circuit as a whole.

References

- [1] "Weather Transmitter WXT530 Series."
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- [3] "FlexiMet Wind 3 System - Wind Measurement with Local Display & Wireless Access to Data | Richard Paul Russell." [Online]. Available: https://www.r-p-r.co.uk/windsystems/fleximet_wind3.php. [Accessed: 28-Dec-2017].
- [4] "WxPRO: Entry-Level, Research-Grade Weather Station." [Online]. Available: <https://www.campbellsci.com/wxpro>. [Accessed: 28-Dec-2017].
- [5] "How to calculate battery run-time when design equipment using batteries; Battery Technical Resources for Design Engineers from PowerStream." [Online]. Available: <https://www.powerstream.com/battery-capacity-calculations.htm>. [Accessed: 30-Dec-2017].
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Weather Data Logger

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

63/100

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GRADING FORM: SMU GENERIC_GJ

GLEN JOSEPH HENLEY**62.55****RESEARCH-INFORMED LITERATURE**

Nice literature review of available systems with a good comparison table of relevant information with a thumbnail image of the device in the table. 70%

10.5**KNOWLEDGE AND UNDERSTANDING**

Good overall schematic design but a few problems can be seen. Din on the Pic should connect to Dout on the sd card, likewise Dout on the Pic should connect to Din on the sd card. Do not connect the VCC to 5V from the USB connector as slight differences between the outputs can cause large currents to flow, instead, connect it to the Pic to allow the firmware to establish a USB connection automatically. Nice pcb layout. 65%

22.75

ANALYSIS

-  Good selection of microcontroller and nice table showing possibilities for choice. Good selection of sensors with a nicely 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. 60%

18

PRACTICAL APPLICATION AND DEP.

-  Costings put forward as a table with price but without supplier of component and a lot lacking detail. Reasonable attempt at future enhancements. 55%

5.5

SKILLS FOR PROFESSIONAL PRAC.

-  The report is reasonably presented with nicely tabled data which could have been improved with more images/illustrations, a structure diagram and flowchart. Limited selection of references. 58%

5.8