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**14 Day Weather and Air
Quality Measurement and
Logging System**

Report

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Monday, 16 January 2023

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ABSTRACT

After some initial research into weather stations and data loggers. I designed my own. In this report I have laid out my process, decisions, and evaluated my own design, with considerations to future iterations. I covered the process of comparing sensors; drawing the Schematic; PCB layout; and its enclosure and power source.

INTRODUCTION

The brief sets out the requirement for a weather station that tracks and stores the following parameters over a 14 day period:

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

LITERATURE REVIEW

DAVIS VANTAGE PRO 2



The vantage Pro 2 made by Davis Instruments [1] is marketed as a professional weather station and when compared to its competitors offers a well-rounded suite of sensors. It's temperature and humidity are comparable to its competitors and its wind measurements with its mechanical vane and cup anemometer can measure very high wind speeds of 200 MPH and a full 360° of direction.

A particulate matter (PM) sensor can be added for £228, and the PM sensor has 3 bins for PM1, PM2.5, and PM10. This 'Airlink' sensor does not measure other pollutants like Volatile Organic Compounds (VOCs). The vantage Pro 2 is the only station compared here to include brightness and ultraviolet measurements. The Light level is measured in W/m^2 which does not account for how humans perceive the intensity in light like the unit LUX does [2] but is a useful as part of determining the viability of photovoltaic panels. [3] The UV level is output as an index which factors the difference harm UVA, UVB, and UVC causes to the skin. There is a discrepancy in the purpose of these two metrics with the UV index factoring in the harm of each UV wavelength, but the light level does not factor in one's perception.

The unit comes with a display that is wirelessly updated, but to include data logging a £42 yearly software subscription is required for the data to be stored online.

The unit includes a mounting pole and can be mounted to a tripod, and the unit is powered by the included solar panels with a back-up battery.

ENVIROTRACK



The EnviroTrack [4] offers a comparable set of weather sensors with a similar maximum range in temperature, humidity, pressure, and rainfall as the vantage Pro 2 but the unit does fall short with its wind measurements. Like the vantage Pro 2, the EnviroTrack uses a mechanical vane and cup anemometer which can measure winds up to an impressive 170 MPH, but the vane includes a 5° dead band, due to the limitation of the potentiometer used.

The EnviroTrack does not allow for additional sensors to be included at purchase or down the line, and off the shelf, no pollution sensors are included.

The unit stores the data locally on 512KB flash, and the sample rate can be set from once per second up to once every 18 hours. With the included battery being rated for one year and the sample rate being user set, this station offers a wide range of time periods that the unit can be left for data logging. The data can be retrieved via USB live or collected at the end of a testing period.

The EnviroTrack is more expensive than the vantage Pro 2 but is missing parameters like brightness, ultraviolet, and pollution monitoring, as well as having a 5° dead band in the wind direction. The EnviroTrack does include a better method of logging, with local storage, and free software.

INTELLISENSE MWS-C600



Intelligence's MWS-C600 [5] is made in the USA and marketed for the aerospace industry and the military. The unit includes the same range of weather sensors as the aforementioned units, but their wind speed has a much lower maximum rating of 58 MPH. This limit could be due to the ultrasonic sensor used, and above a set wind speed, aircraft are not able to operate, so the speed would not need to be quantified after aircraft are grounded.

The unit includes some additional sensors that are practical for aviation, like the cloud height sensor, which can measure the height of the cloud ceiling below 3048 m (10,000 ft) and also includes a visibility sensor, which can measure the distance one can see up to 10 KM. The pollution monitoring of the station is limited, and falls short of the Vantage Pro 2, because this station only measures PM and does not specify the size of particulate or the definition of their 0-100% scale in the product's datasheet, leaving the reading quite redundant.

The data can be transmitted wirelessly and used with Intelligence's paid software or can be accessed via USB.

PURPLEAIR PA-II-FLEX



The PA-II-FLEX by PurpleAir [6] is a pollution monitoring station but includes sensors for some weather metrics. As the brief requires some pollution monitoring, it is worthwhile to look at a product designed with that as its primary function. The temperature, humidity and pressure capabilities match or exceed the previously discussed models, but rain, wind speed and direction is not included.

The unit includes two duplicate PM sensors with six bins for PM0.3, 0.5, 2.5, 5, 10, allowing for precise and accurate data. The unit measures VOCs with a Bosch BME680 sensor which reports the levels of VOCs in the air following the Index for Air Quality (IAQ), which categorises the level of pollutants into 7 levels from 'excellent' to 'extremely polluted'. By not measuring pollution in parts per billion (ppb), has limited its use for scientific studies but is still suitable for people to assess their exposure.

Model	Davis Vantage Pro2	EnviroTrack	MWS-C600	PurpleAir PA-II-FLEX
Temperature	-40 to +65°C	-40 to +65°C	-40 to 60°C	-40 to 85°C
Humidity	0% to 100%	0% to 100%	0% to 100%	0% to 100%
Pressure	included	included	600 to 1110 hPa	300 to 1100 hPa
Wind	2-200 mph / 360°	0-170 mph / 355°	0-58 mph / 360°	n/a
Rain	rainfall in mm	rainfall in mm	rainfall in mm	n/a
Cloud Ceiling	n/a	n/a	0 to 3048 m	n/a
Visibility	n/a	n/a	10 to 10,000 m	n/a
PM	1,2.5,10	n/a	0 to 100%	0.3, 0.5, 1.0, 2.5, 5, 10
VOC	n/a	n/a	n/a	IAQ
Light	W/m ²	n/a	n/a	n/a
UV	UV index (1-10+) and intensity over time	n/a	n/a	n/a
Mounting method	pole included	tripod included	pole	wall mounted
Data out	wireless to display	USB	wireless and USB	
Power	Solar with battery backup	battery for 1 year	Solar with battery backup	DC 5V 0.9W
Logging method	no local storage £42/year for cloud storage	local storage 512KB 19.5hrs @ 1 sec sample rate 8 years @ 1 hr sample rate free software	no local storage paid software (raw data over serial available)	SD card and real time clock free cloud storage
price	£1,714.13	£1,824.05	price on request	£244.37

DESIGN

SENSORS

Temperature, Humidity and VOC Level

Temperature and Humidity is commonly included on a range of other sensor types, so I included their capability in the table.

VOCs describe compounds carried in the air and although most VOCs are emitted by plants for their defence and communication [7], The term VOC is most commonly used to describe human sources like Fossil fuel use and production, Solvents used in coatings, paints, and inks, and butane and propane from Compressed aerosols. [8] These man-made compounds have an adverse effect on people's long-term health, with very high concentrations able to cause short term affects like headaches, coughing, and skin irritation.

Manufacturer	S + S.de	Sensirion	AMPHENOL	TE CONNECTIVITY	Bosch
name	ALQ-CO2-W	SEN54-SDN-T	MICS-VZ-89TE	2316852-1	BME680
temperature range	-10 to +60 °C	+15 to +30 °C	0 to +50°C	+5 to +50°C	-40 to +85 °C
Humidity Range	0% to 100%	30% to 70 %	0% to 95%	5% to 95%	0% to 100%
VOC Scale	0–100%	index	0-1000ppb	0-1187ppb	index
other sensors	CO2	PM, NOx	CO2	CO2	air pressure
Data output	USB or RS485	I2C	PWM	I2C	I2C, SPI
Power	4.4 W	350 mW	125 mW	109 mW	40 mW
price	£532.60	£32.66	£20.78	£25.11	£11.71

I will use the Bosch BME680 as is the only sensor that will operate in outdoor temperatures, except the ALQ-CO2-W, which cost over £500 and has a very high power consumption. The BME680 has the lowest power consumption, lowest price, and operates in the greatest number of weather conditions.

This device includes a high quality temperature sensor, covering a range suitable for outdoor use and a great accuracy of 0.5°C at 25°C and 1°C at the periphery of its range. The humidity sensor has an acceptable accuracy of 3%. With the temperature and humidity sensors being suitable, I won't include a dedicated device for each.



Wind Speed and Direction

Wind direction can be measured mechanically with a vane, which is a horizontal arm holding a vertical flat plate. The arm is free to rotate and its angle can be measured. Wind speed can be mechanically measured with a cup anemometer, which is three or four conical cups mounted to a vertical spindle. The spindle is free to rotate in the wind, and its speed of rotation is proportional to the wind speed. Both wind speed and direction can be measured with a sonic anemometer, which has no moving parts and uses a sonic transmitter and receiver to determine the speed and direction.

Manufacturer	B & G	FT Technologies	Omni Instruments	Omni Instruments
Manufacturer part no	608 Wind sensor	FT742	WindSonic60	WindSonic75
Price	£439.99	upon request	£812.00	£1,029.00
Speed Range	0.25 - 50 m/s	0 - 75 m/s	0 - 60 m/s	0 - 75 m/s
Speed Accuracy	± 0.1 m/s	± 4%	± 2%	± 2%
Direction Range	360	360	360	360
Direction Accuracy	0.5 deg	5 deg	+ - 2%	+ - 2%
Operating temperature	-25 to 65°C	-40 to 85°C	-35 to 70°C	-35 to 70°C
Operating Power	solar	12v, 348mW	12v, 528 mW	12v, 528 mW
Data Output	Bluetooth	RS485	0-5V, 0-20mA or 4-20mA	0-5V, 0-20mA or 4-20mA

The wind conditions will be made up of the prevailing conditions but will also include gust of wind that will be an order of magnitude faster and could have a differing direction. The highest recorded speed in the UK was 77.3 m/s in 1986. I will use the Omni Instruments WindSonic75 as it can measure speeds up to 75 m/s and has an improved accuracy and simpler data output method than the FT Technologies FT742.



Airborne Particle Count

Particulate Matter (PM) is a term to describe a mixture of solid particles and liquid droplets found in the air. They can be described by their diameter, with particles less than $10\mu\text{m}$ categorised as PM10, particles less than $2.5\mu\text{m}$ categorised as PM2.5, and less commonly mentioned sizes like PM1 and PM4. PM10 are small enough to be breathed in and make their way to the lungs, and cause health implications to the lungs and heart. PM2.5 are small enough, so that they can make their way into the bloodstream after being inhaled, and they can have broad health implications. [1]

PM is measured in $\mu\text{g}/\text{m}^3$, describing the mass within a volume of air. This is due to the traditional method of measuring PM with the gravimetric method. [2] This method makes use of a filter set for a specific size or particulate like PM10, and the filter would be left for a time period, and after sampling, the filter would be weighed, and the volume of the airflow used to calculate the mass concentration in $\mu\text{g}/\text{m}^3$. This method has long been established as the most accurate way of measuring the mass concentration, but they are limited to only measuring one PM size as this is set by the filter used, and real time sampling isn't possible.

Newer methods of measuring PM have been devised often using optical detection, with light scattering or, the less often, light absorption method being used. Both methods rely on a light source, often a laser, being scattered or absorbed by the passing particles, and a photodiode measuring the output of the light source. An optical PM sensor counts the number of particles and estimates the mass concentration. As well as providing an estimate of the mass concentration, optical sensors can also count the number of particles and output the data in real time.

Manufacturer	Sensirion	Plantower	Honeywell	Honeywell	Winsen	Winsen
Manufacturer part no	SPS30	PMS-6003	HPMA115S0-XXX	HPMA115C0-003	ZH03B	ZPH01
Price	£47.04	£60.32	£59.96	£83.20	£41.21	£37.24
particulate size	PM 1, 2.5, 4 and 10	PM 1, 2.5 and 10	PM2.5	PM 2.5 and 10	PM2.5	PM2.5 and VOC
Supply voltage	5 Vdc	5 Vdc	5 Vdc	5 Vdc	5 Vdc	5 Vdc
Operating Power	0.3 W	0.5 W	0.4 W	0.4 W	0.6 W	0.75 W
Standby Power	0.04 W	1 mW	0.1 W	0.1 W	0.1 W	0.1 W
Operating temperature	-10 to 60°C	-10 to 60°C	-10 to 50°C	-20 to 50°C	-10 to 50°C	-10 to 50°C
Operating RH	0-95%	0-99%	0-95%	0-95%	0-95%	0-95%
Data Output	UART	UART	UART	UART	UART or PWM	UART or PWM

I chose the Sensirion SPS30 as it is the cheapest sensor to include separate measurements of PM2.5 and PM10. The SPS30 also has the lowest operating power consumption and one of the lowest standby power consumption.



Sunlight brightness

Sunlight brightness can be measured in either the SI unit lux, which describes the intensity of light perceived by the human eye. It is derived from W/m^2 but each wavelength is weighted by their luminosity function.//cite The brightness could also be measured in W/m^2 , which is what the MET Office uses.

Manufacturer	Omni Instruments	S + S	Omni Instruments	Omni Instruments
Manufacturer part no	LL-P-V	PHOTASGARD® AHKF	SP Lite2 Silicon Pyranometer	CMP3 Pyranometer
Price	£62.61	£95.98	£405	£717
Sensor Type	photodiode	photodiode	photodiode	thermopile
Spectrum Range		350 nm and 820 nm	400 to 1100nm (violet to IR)	300 to 2800nm
range	10 to 2,000 Lux or 10 to 10,000 Lux	0 to 500 Lux/ 1 kLux/ 2 kLux/ 5 kLux/ 20 kLux/ 60 kLux	2000 W/m^2	2000 W/m^2
accuracy	5%	5%	<10 W/m^2	<20 W/m^2
Operating Power	24V	24v, 1W	-	-
Operating temperature	-10 to +50°C	-30 to +70°C	-40 to +80°C	-40 to +80°C
Data Output	0 - 10 V	0 - 10 V or 4-20mA	0 to 100 mV	0 to 30mV

I have chosen to use the PHOTASGARD by S + S. I wanted to use a sensor that measured the brightness in LUX as this factors the human perception on light intensity. The two pyranometers measure wavelengths not visible to the human eye like infrared and ultraviolet.



UV Level

model	CUV5	SUV A	SUV B
UV range	UVA + UVB	UVA	UVB
Spectral range	280 to 400nm	315 to 400nm	280 to 315nm
Sensitivity	300-500 μ V/Wm ²	10 μ V/Wm ²	100 μ V/Wm ²
Field of view:	180°	180°	180°
Maximum irradiance	400 W/m ²	90 W/m ²	p W/m ²
power	-	55mW @ 12vDC	55mW @ 12vDC
price	3,023.00	4,104.00	4,765.00

The range of UV sensors on the market is quite limited, making it a very expensive parameter to include in a weather station. I choose the CUV5 as it covers both UVA and UVB, doesn't require power, and is the cheapest.



GPS Position

Manufacturer	ST	DF Robot	LANTRONIX	LANTRONIX	LANTRONIX
Manufacturer part no	TESEO-LIV3R	TEL0132	A2200A	A5100A	A2235H
Price	£12.28	£18.85	£15.42	£16.96	£21.30
Accuracy	1.8m	2.5m	2.5m	2.5m	2.5m
Standby power	17 μ W	-	82 μ W	594 μ W	89 μ W
Tracking Power	70 mW	82 mW	135 mW	102 mW	72 mW
Time to first fix	36 sec	32 sec	35 sec	35 sec	35 sec
Data output	I2C, UART	I2C	I2C, SPI, UART	I2C, SPI, UART	I2C, SPI, UART
mounting type	PCB	module	PCB	PCB	PCB

I have chosen to use the TESEO-LIV3R by STMicroelectronics, it has the highest accuracy, lowest standby and tracking power consumption, with a comparable time to first fix from a cold start. It is also the cheapest and can be soldered directly to the PCB.



MICROCONTROLLER

To choose the microcontroller (MCU) for this project I used Microchip's part selector [9] to find a suitable 8-bit PIC microcontroller. As the system will be running from a battery for a 14 day period, Microchips XLP (extra low power) feature would be advantageous, and I determined the number of pins required for the peripherals.

Type	Purpose	Total pins
Analogue Input	Wind speed and direction, Light level, and Ultraviolet.	4
SPI	Micro SD card and VOC sensor (CLK, MISO, MOSI, CS1, CS2)	5
I2C	Real Time Clock (CLK, DATA)	2
UART	Particulate Matter (TX, RX)	2
Digital Output	LED and MOSFET	2
USB	D+ and D-	2
Programmer	PGC, PGD, MCLK	3

Total: 20

Parameter Search
☒ Match ALL (AND)
 ☐ Match ANY (OR)
 Collapse

Family: 8-bit MCU
 Part Family: -All-
 CPU Type: 8-bit PIC MCU
 Max CPU Speed (MHz): -All- -All-
 CPU Speed (MIPS/DMIPS): -All- -All-
 ☐ ARM Neon
 ☐ FPU
 ☐ Math Accelerator
 ☒ 8-bit
 ☐ 16-bit
 ☐ 32-bit
 --- Product Status ---
 ☒ Current
 ☒ Future
 ☐ Mature

Voltage
 Operation Voltage: -All- -All-

Temperature
 Temp Range: -All- -All-

Packages
 Pin Count: -All- -All-
 Max I/O Pins: 20 -All-

Low Power
☒ Low Power
 ☒ XLP
 ☐ Vbat/Vddbu battery backup

Four analogue to digital converters (ADC) are required for the analogue signals. I set the resolution to 10-bit as it will be sufficient. Most of the sensors use serial communication, including UART, SPI and I2C, so I have included one of each. USB is also required for accessing the data.

Analog Peripherals			
ADC Input	4	-All-	☐ Temp Sensor
Max ADC Resolution (Bits)	10	-All-	☐ CTMU
DAC Outputs	-All-	-All-	☐ Zero Cross Detect
Communication			
UART	1	-All-	
SPI	1	-All-	
I2C	1	-All-	
I2S	-All-	-All-	
SSC	-All-	-All-	
USB			
Number of USB Modules	1	-All-	
USB Interface	-All-		
☐ USB Active Clock Tuning			

After entering the requirements into the part selector, there were 23 suitable MCUs left. I sorted by price, and the cheapest option was the PIC16F1459. I also selected the PIC18F13K50 and the more premium PIC18F24J50 from the “J” series.

Search Results		23 MCHP parts found	
PIC18F24J50 PIC18F24J50 PIC18F45K50 PIC18F25K50 PIC18F24K50 PIC16F1459		Reset Search Sort Results by Price Add PIC16F1459 Go to side-by-side	
To add MCHP part to side-by-side:			
Automotive Capable:		☐	

	PIC16F1459 Microchip delete	PIC18F13K50 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	(1.8V-5.5V)	(1.8V-5.5V)	(2V-3.6V)
Temp Range	(-40 to 125)	(-40 to 125)	(-40 to 85)
Pin count	20	20	28
Program Memory Size (KB)	14 Flash	8 Flash	16 Flash
Error Correction Code Program Flash			
SRAM	1024 Bytes	512 Bytes	3.7109375 KB
Data EEPROM/HEF (Bytes)		256	
Internal DRAM Type			
Internal DRAM Amount (MB)			
Low Power	Yes	Yes	Yes
ADC Input	9	9	10
Max ADC Resolution (Bits)	10	10	10
DAC Outputs	1		
Number of Op Amps			
Hardware Touch Peripheral			
UART	1	1	2
SPI	1	1	2
I2C	1	1	2

Whilst I was comparing the MCUs I found that if I wanted to use SPI and I2C serial communication in the same design, the PIC would have to include two Master Synchronous Serial Ports (MSSP). The data sheets for the PIC16F and PIC18F13K indicate that one MSSP is included. The PIC18F24J50 includes two MSSP for SPI and I2C, as well as UART.

Only having one MSSP can be worked around by using a method called bit banging, which is the method of using software and coding the communication protocol rather than using the dedicated hardware. Due to the added complexity of bit banging, and the PIC18F24J50 is readily available with two MSSP, I have chosen to use the PIC18F24J50.

PIC18F46J50 FAMILY

PIC16(L)F145X Family Types

Device	Data Sheet Index	Program Memory Flash (words)	Data SRAM (bytes)	I/Os ⁽²⁾	10-bit ADC (ch)	Comparators	DAC	Timers (8/16-bit)	PWM	EUSART	MSSP (I ² C™/SPI)
PIC16(L)F1454	(1)	8192	1024	11	—	—	—	2/1	2	1	1
PIC16(L)F1455	(1)	8192	1024	11	5	2	1	2/1	2	1	1
PIC16(L)F1459	(1)	8192	1024	17	9	2	1	2/1	2	1	1

PIC18F/LF ⁽¹⁾ Device	Pins	Program Memory (bytes)	SRAM (bytes)	Remappable Pins	Timers 8/16-Bit	ECCP(PWM)	EUSART	MSSP	
								SPI w/DMA	I ² C™
PIC18F24J50	28	16K	3776	16	2/3	2	2	2	Y
PIC18F25J50	28	32K	3776	16	2/3	2	2	2	Y
PIC18F26J50	28	64K	3776	16	2/3	2	2	2	Y
PIC18F44J50	44	16K	3776	22	2/3	2	2	2	Y
PIC18F45J50	44	32K	3776	22	2/3	2	2	2	Y
PIC18F46J50	44	64K	3776	22	2/3	2	2	2	Y

POWER

I created a table in excel to calculate the average power each sensor would use in an hour as the sensor would spend the majority of the time in standby mode until it is called to take a measurement at a specified interval. I calculated the average power with this equation:

average power

$$= \left(\text{measuring power} * \frac{\text{seconds active}}{3600 (\text{seconds in an hour})} \right) + \left(\text{standby power} * \frac{\text{seconds in standby}}{3600 (\text{seconds in an hour})} \right)$$

Component	standby W	measuring W	standby/active ratio	seconds of use in 1 hr	average power
PIC	42.9E-9	660.0E-3	1 sec every 10 sec	360	66.0E-3
Green LED	000.0E+0	3.8E-3	1 sec every 10 sec	360	380.0E-6
Red LED		1.6E-3	Always on	3600	1.6E-3
MOSFET	000.0E+0	8.9E-3	1 sec every 10 sec	360	887.5E-6
3.3 V Regulator	1.2E-3	256.3E-3			1.20E-03
5 V Regulator	840.0E-6	420.0E-3			6.43E-03
Wind speed + direction	000.0E+0	528.0E-3	1 sec every 10 sec	360	52.8E-3
Brightness	000.0E+0	1.0E+0	1 sec every 10 min	6	1.7E-3
Ultraviolet	000.0E+0	000.0E+0	1 sec every 10 min	6	000.0E+0
op amp for UV	5.0E-6	1.8E-3	1 sec every 10 sec	360	179.5E-6
Particulate	40.0E-3	400.0E-3	8 sec every 10 min	48	44.8E-3
Temperature	16.5E-6	1.2E-3	1 sec every min	60	35.5E-6
Humidity	16.5E-6	1.1E-3	1 sec every min	60	34.9E-6
VOC	16.5E-6	39.6E-3	1 sec every 10 min	6	82.5E-6
RTC	4.0E-6	990.0E-6	1 sec every 10 min	6	5.6E-6
SD Card	4.1E-3	264.0E-3	1 sec every 10 sec	360	30.1E-3
GPS	17.0E-6	70.0E-3	36 seconds once/day	1.5	46.2E-6

TOTAL: 206.3 mW

The PIC I choose has a feature called XLP (extra low power) which allows the pics current draw to be as low as 13nA. The PIC can use the onboard clock as a wake-up signal. I determined that the PIC would be active for 1 second for every 10 seconds as that is the highest frequency of the of the sensors.

I choose to use 2 very low power LEDs that are manufactured by Broadcom. This red LED only draws 1.6 mW, whereas a typical 20mA @ 2.2 V LED would draw 44 mW. The green LED will flash for one second every 10 seconds as per the brief.

I have included a MOSFET in the design to create an open drain output, to allow me to switch off certain sensors that do not have a standby mode. It will use some power, but the cost is recouped by not running some of the sensors for 24 hours a day. I set the MOSFET's standby active time to the sensor with highest frequency.

The LDO linear regulators will have a low quiescent current, and they will use the most power during use.

Wind speed and direction, and brightness use the open drain to prevent power draw during standby. I also use the same signal for the MOSFET gate for the enable pin on the operational amplifier for the UV sensor.

The PIC will communicate with the Real Time Clock (RTC) once every 10 minutes, and the onboard oscillator will be used to keep track of the time in between. The RTC uses more power during communication.

The SD Card has a standby current draw and a higher read/write current draw. I used Lui Gough's research to estimate a value for the card I used as this data is not often shared by the manufacture. [10]

The GPS Sensor uses 17 μW in stand by and 70 mW when tracking. I decided to get the GPS location once per day, and the sensor requires 36 seconds to fix on to its location from a 'cold start'. I averaged out the 36 seconds per day to 1.5 seconds per hour for the purpose of calculating the average power consumption.

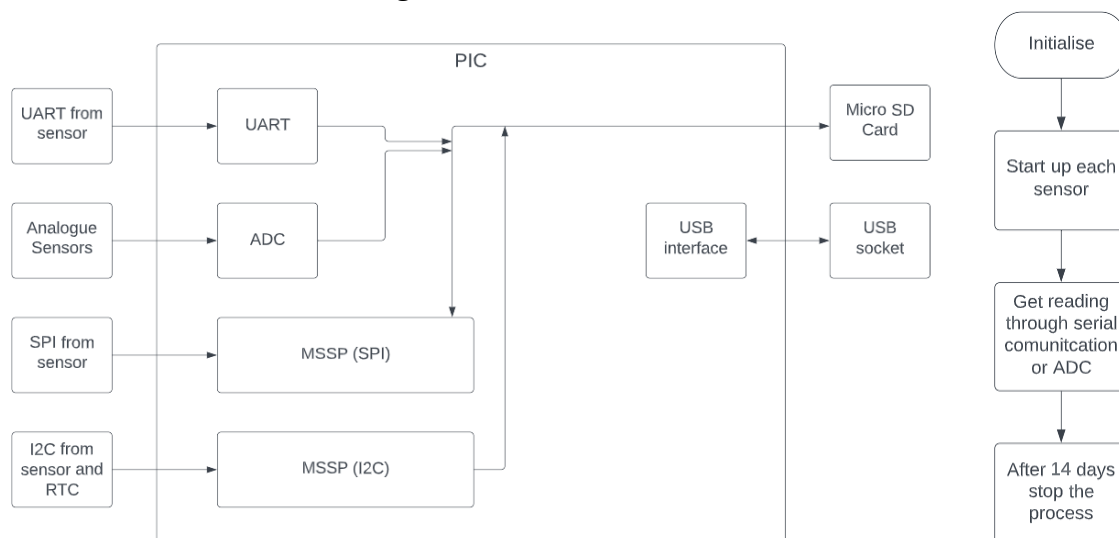
BATTERY

The total average power the unit will consume per hour is 206.3 mW. As the unit is required to last for 14 days. The battery would need to have a capacity of 70WH.

To prevent excessive where on the batteries I will limit their use to a depth of discharge of 50%. This will require double the capacity of 140WH. The design calls for two 12V batteries, so I will use two 12V, 7Ah batteries for a total capacity of 168Wh.

SOFTWARE

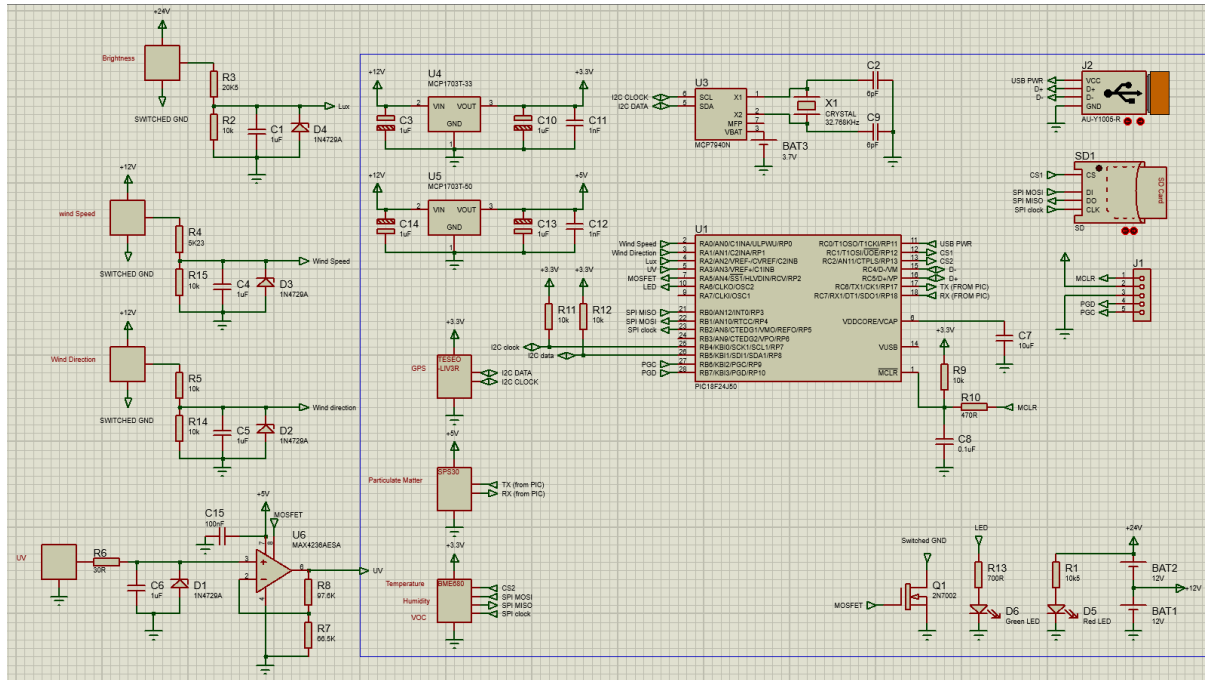
The Block and Flow diagram.



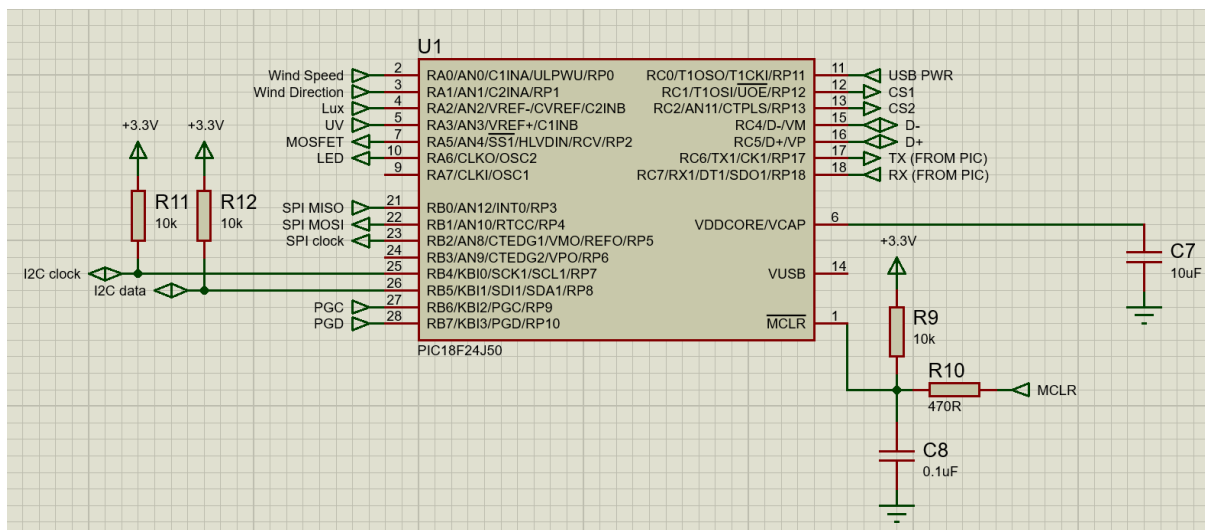
PCB

Proteus

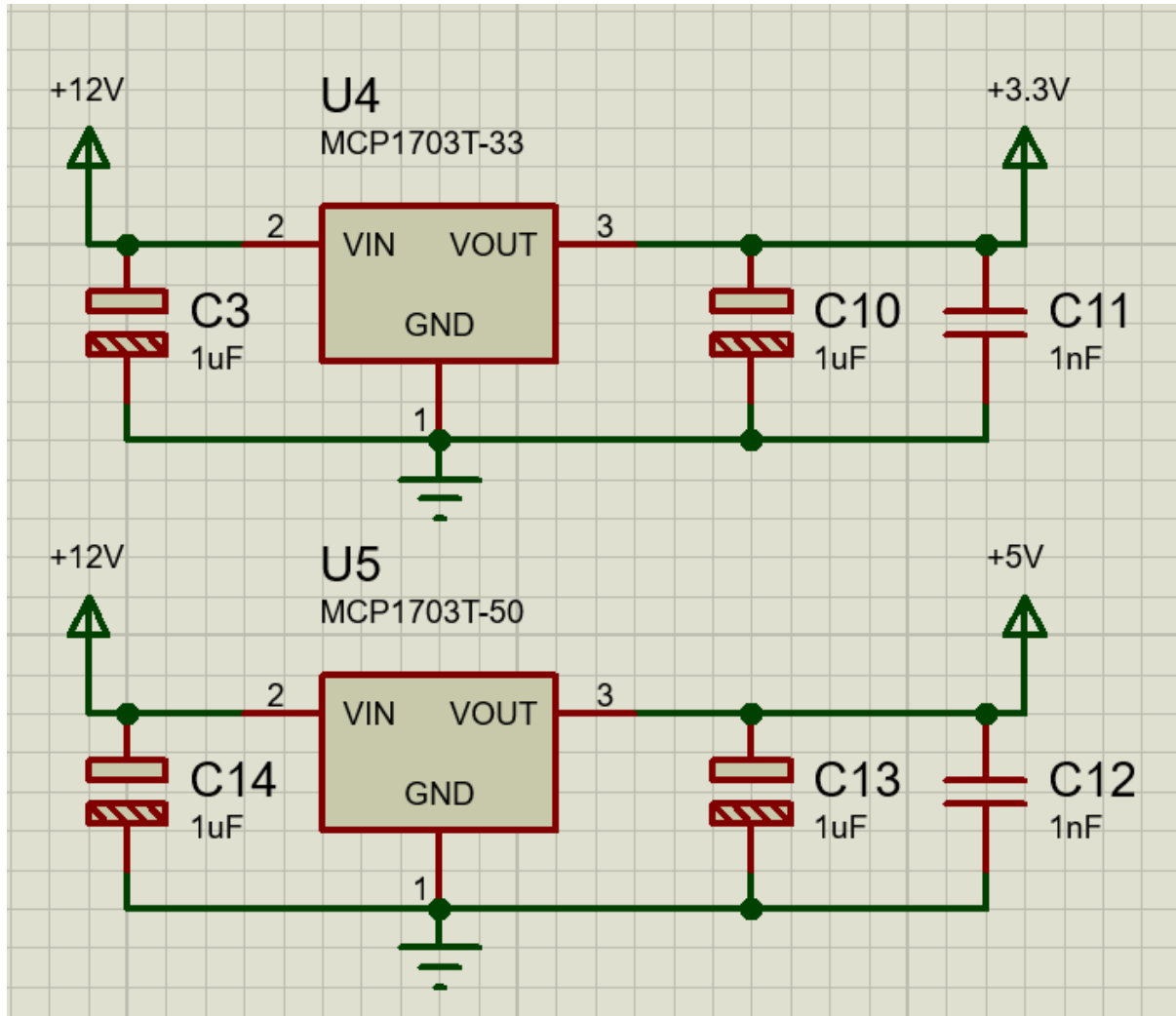
I firstly designed a schematic in Proteus. I created blocks for the sensors and then I designed the signal conditioning required for each of the sensor.



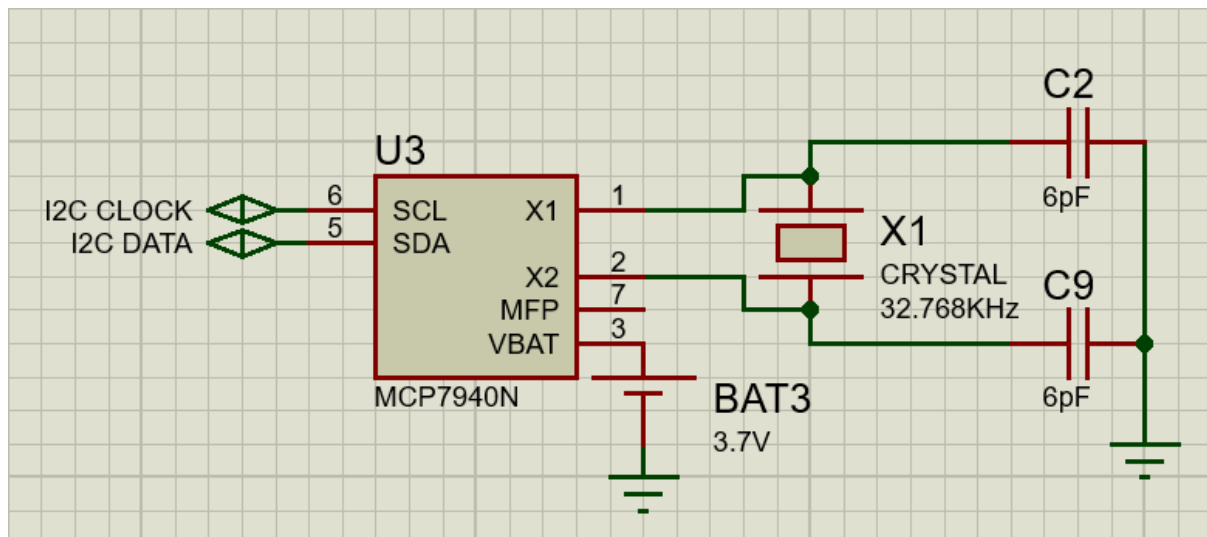
I previously choose the PIC18F24J50. I labelled the USB, UART and I2C pins following the PICs datasheet. I also added the required I2C pull-up resistors. As the first MSSP is used for the I2C I need to connect the SPI to pins that support being reconfigured for serial communication. The datasheet showed that pins RP3, 4, 5 are suitable for SPI. I added some required passive components specified by the datasheet for the programmer and power pins, as well as the other pins for programming.



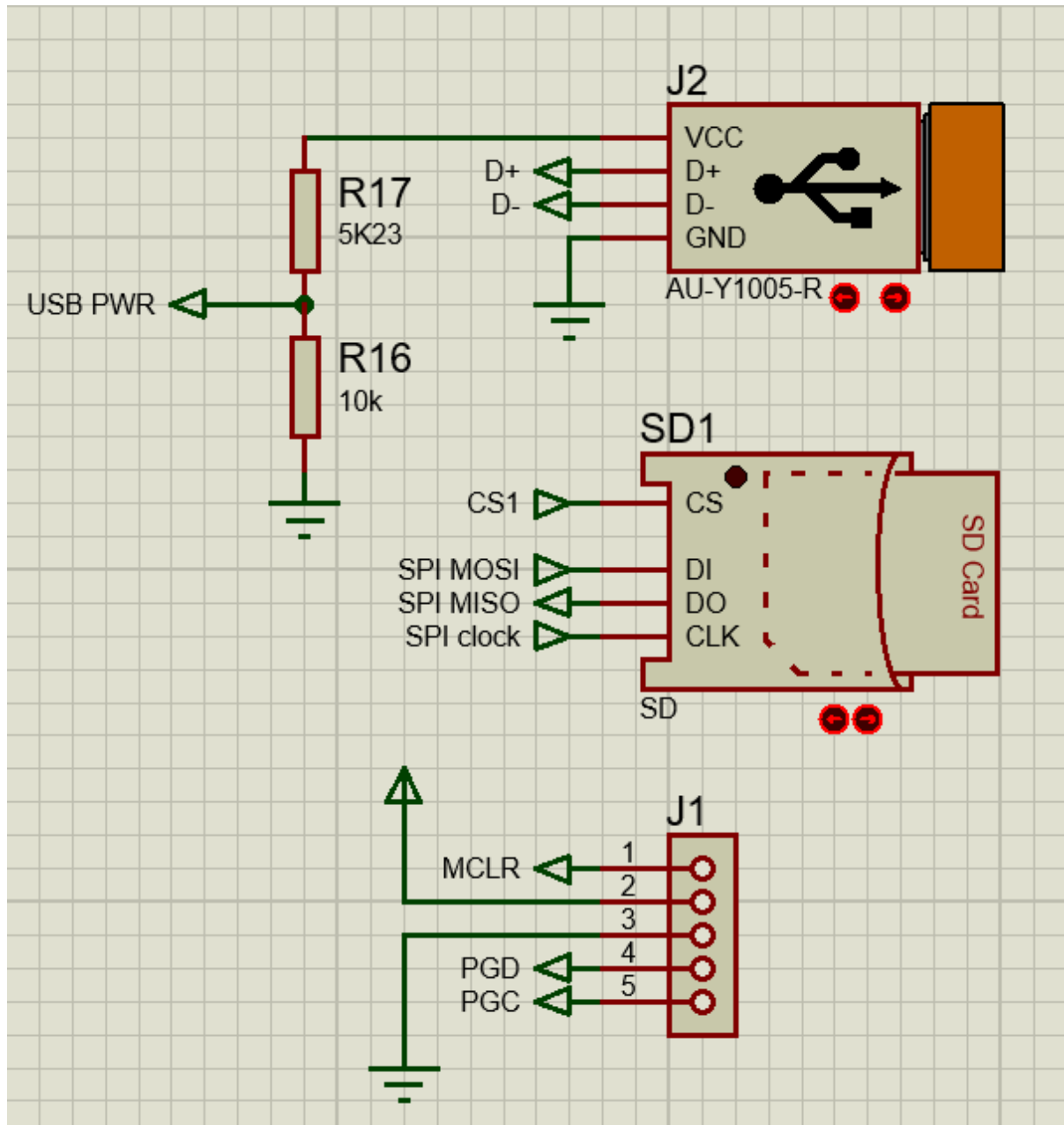
The design requires both 3.3V and 5V so I have included a LDO linear regulator for each. I used a Infineon TLE42744GSV33HTMA1 for the 3.3V regulator which is rated for up to 400mA, as I will require up to 365mA. I will use the Microchip MCP1790 for the 5V regulator which is rated for up to 70mA, as I will require up to 60mA.



I included a Real Time Clock (RTC) to keep track of the date and time. It is powered by a separate 3.7V lithium-ion battery which has the capacity to last up to 18 years. This will be important when the 12V batteries are removed for charging, otherwise the RTC would lose track of the date and time. The RTC requires a 32.768KHz crystal which in turn requires 6-9pF capacitors. The RTC uses I2C to communicate with the PIC.

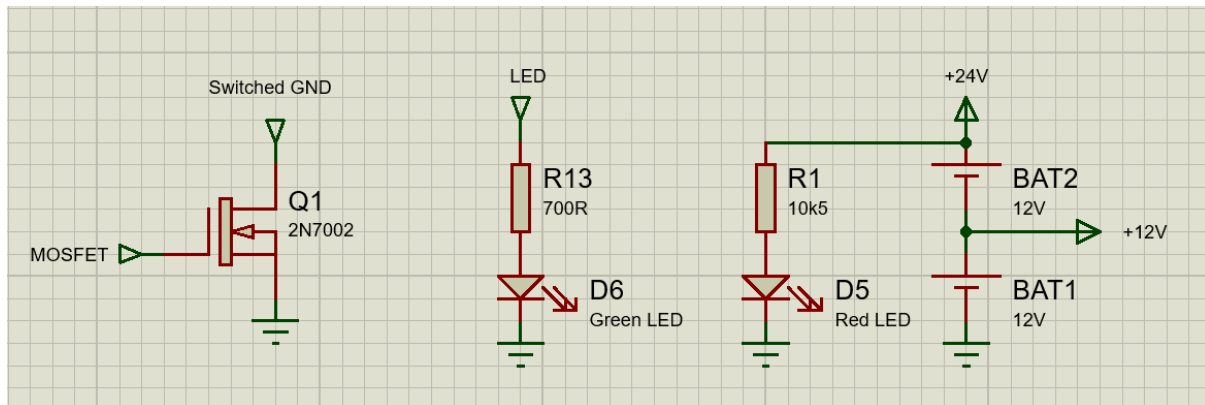


I connected the USB power pin the to the PIC so that The PIC can detect when the USB cable is connected. As the USB operates at 5V and the PIC supports up to 3.3V I used a voltage divider. The SD card reader uses SPI and I designated it as 'chip select 1' (CS1). The programmer port is for the PICKIT3 programmer and debugger tool.



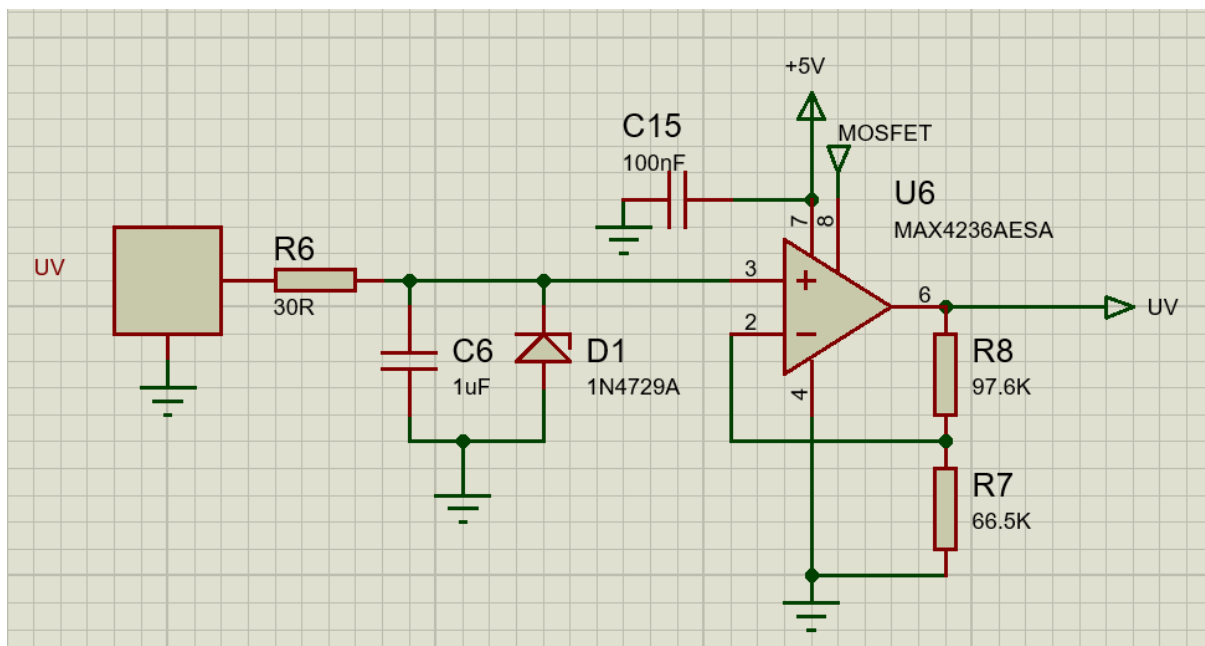
Two of the sensors require 24V. I have included two connectors so that two 12-volt batteries can be used. I included a red LED as a power indicator and a suitable current limiting resistor for 24V. I also included a green LED as per the brief and used a suitable current limiting resistor for the 3.3V PIC output.

As part of saving power, I included a 2N7002 N-channel MOSFET to design a open drain, to switch some of the sensors off as they do not included a standby mode. The MOSFET gate is connected to the PIC. The max current rating of the 2N7002 is 115mA and these sensors only draw 86mA.

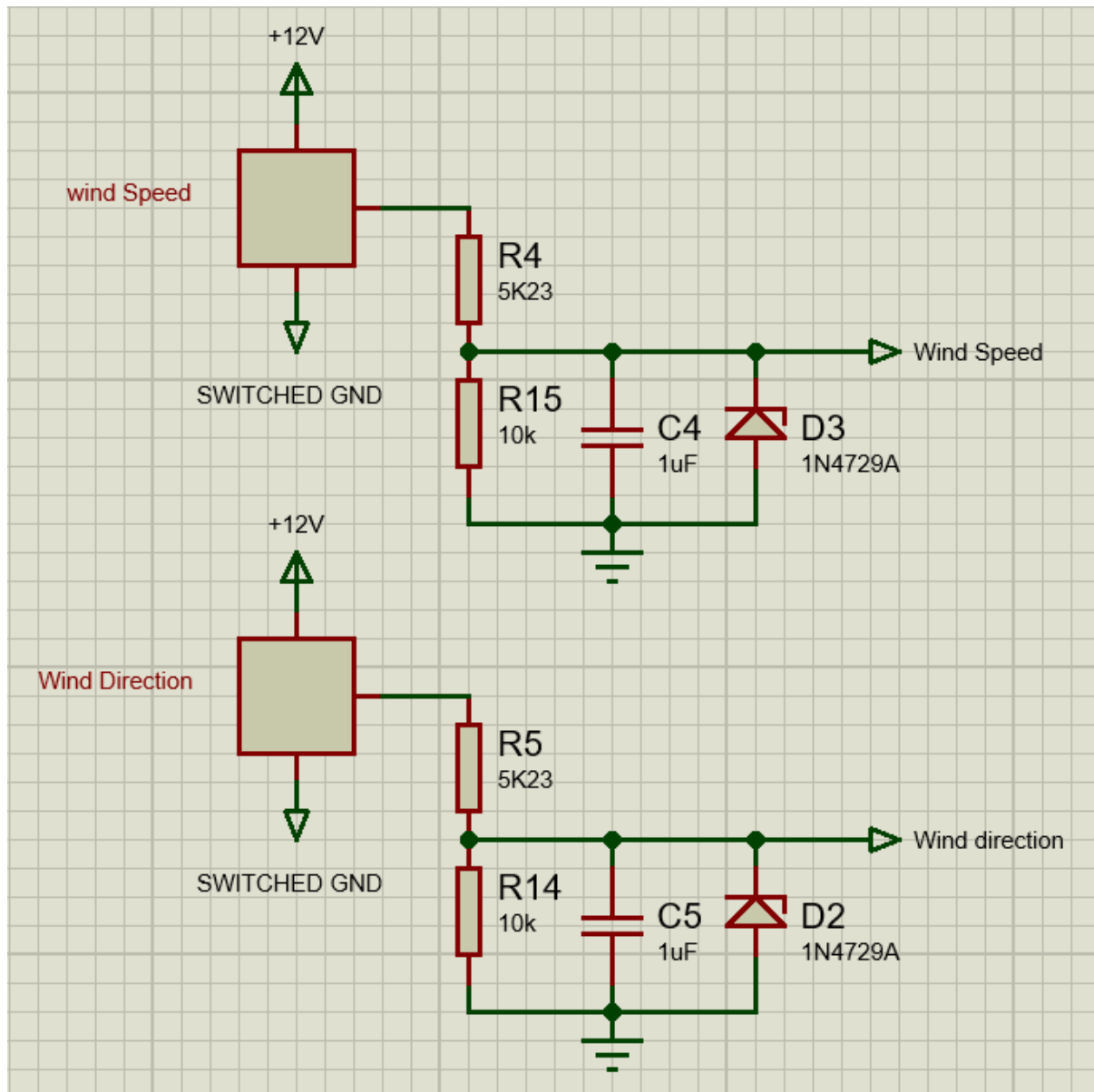


The UV sensor does not require power, but it produces a very small output voltage so a non-inverting operational amplifier is required. I require a gain of 2.5, as I want some headroom to prevent the op amp from outputting a voltage greater the 3.3V, I choose the resistors 97.6K and 66.5K as this has a gain of 2.47.

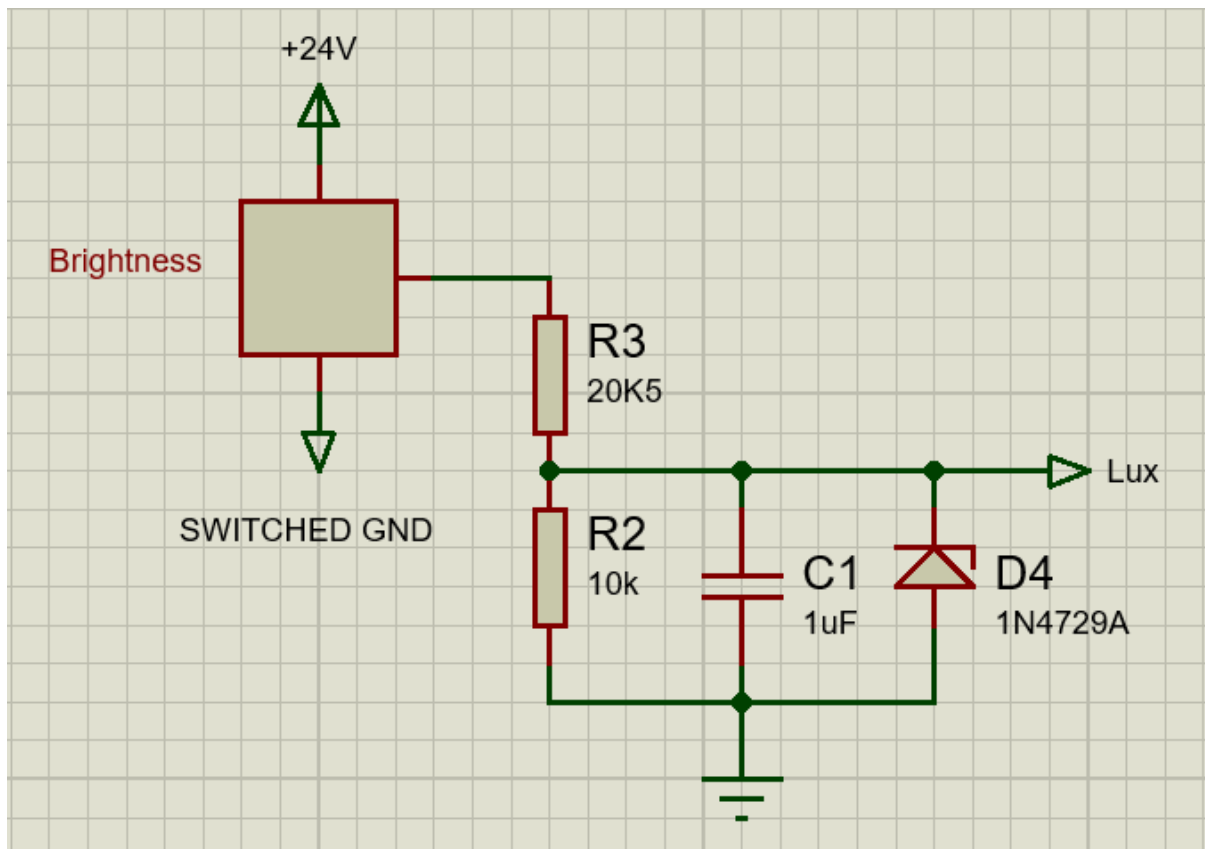
The op amp specifies a 100nF capacitor on the positive rail and I am using a 5V supply even though the amp is 'rail to rail' as it can only achieve 150mV from the supply. The MAX4236 includes an enable pin, that stops the output when low. I connected the enable pin to the same signal as the MOSGET gate.



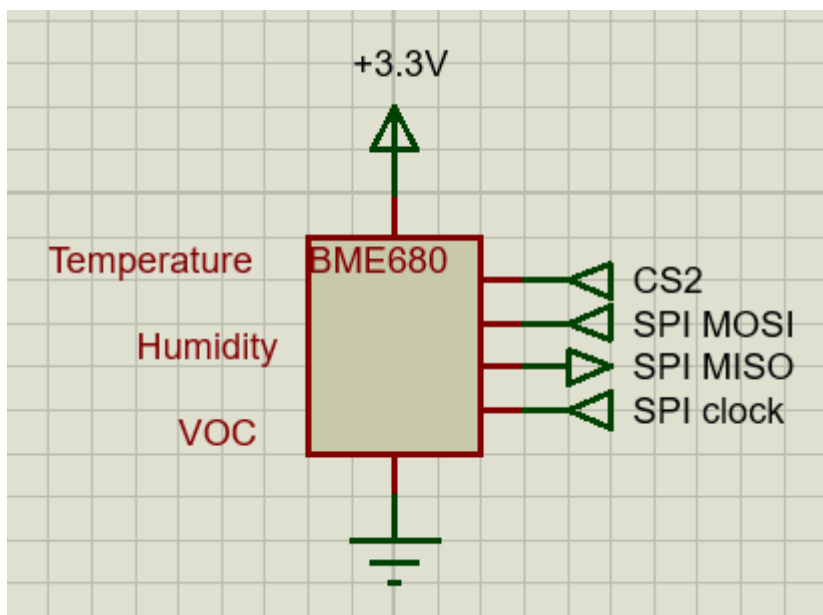
The wind speed and direction sensors output an analogue 5V signal so I used a voltage divider to limit the maximum voltage to 3.3V and I included a 3.6V Zener diode.



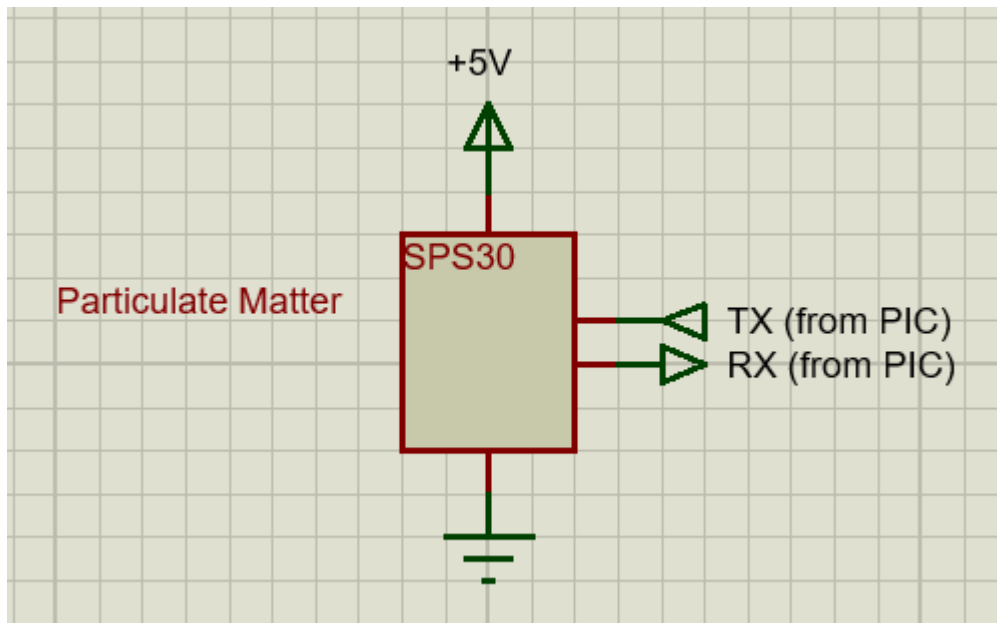
The Lux sensor does not include a standby mode, so the ground is connected to the MOSFET open drain switch. The signal is 0 to 10V analogue so I included a voltage divider, as well as a 3.6V clamp.



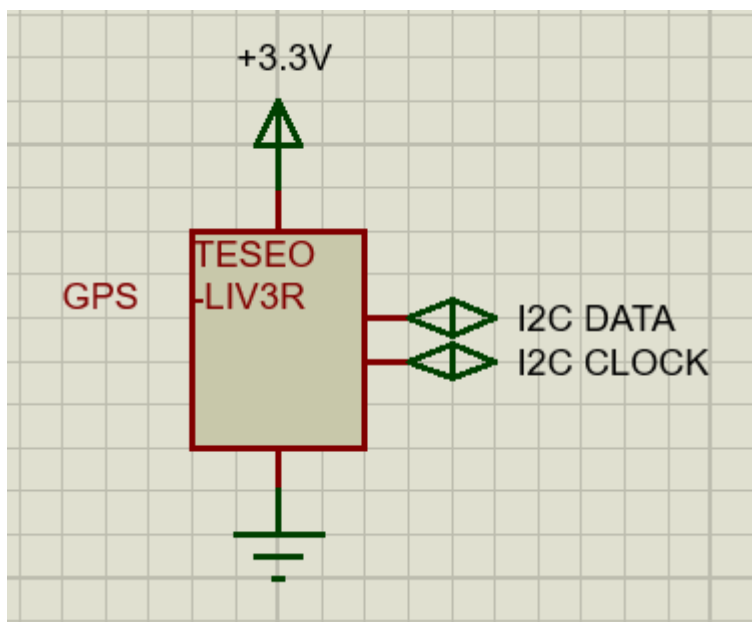
The BME680 uses SPI and requires 3.3V.



The PM sensor requires 5V and uses UART.

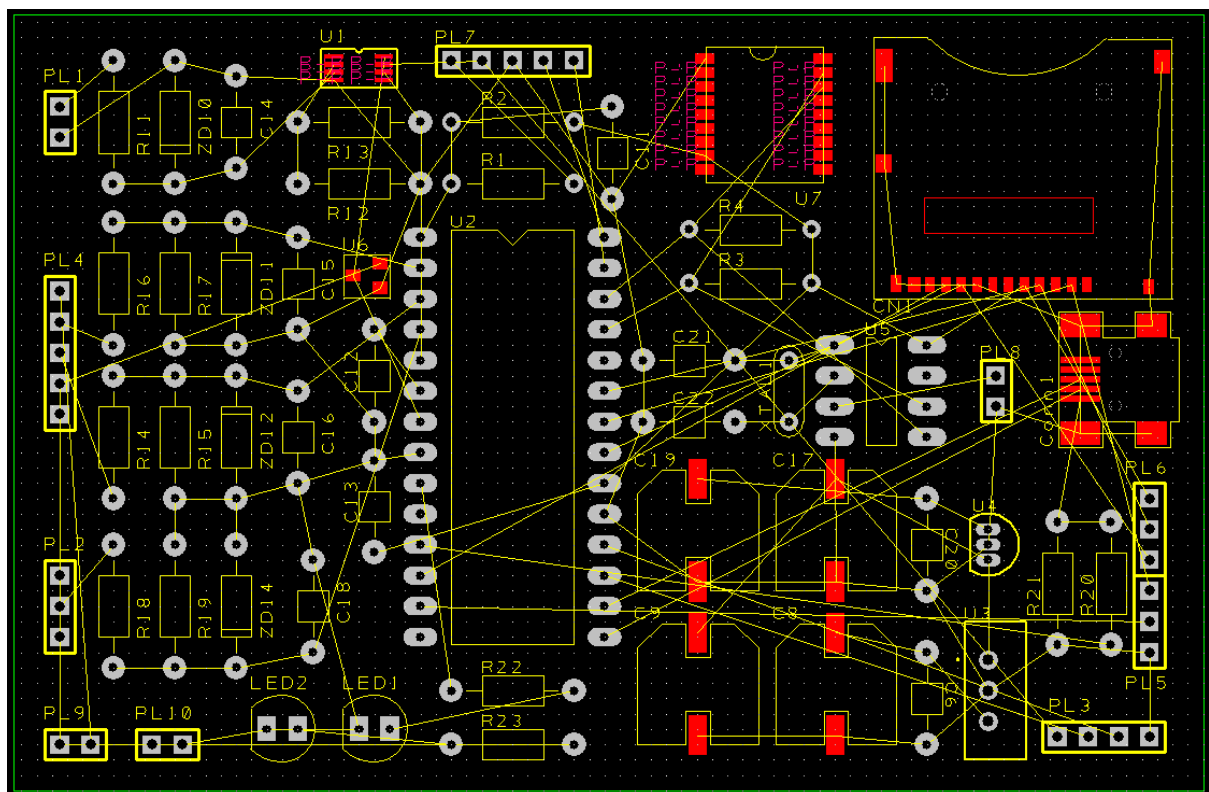
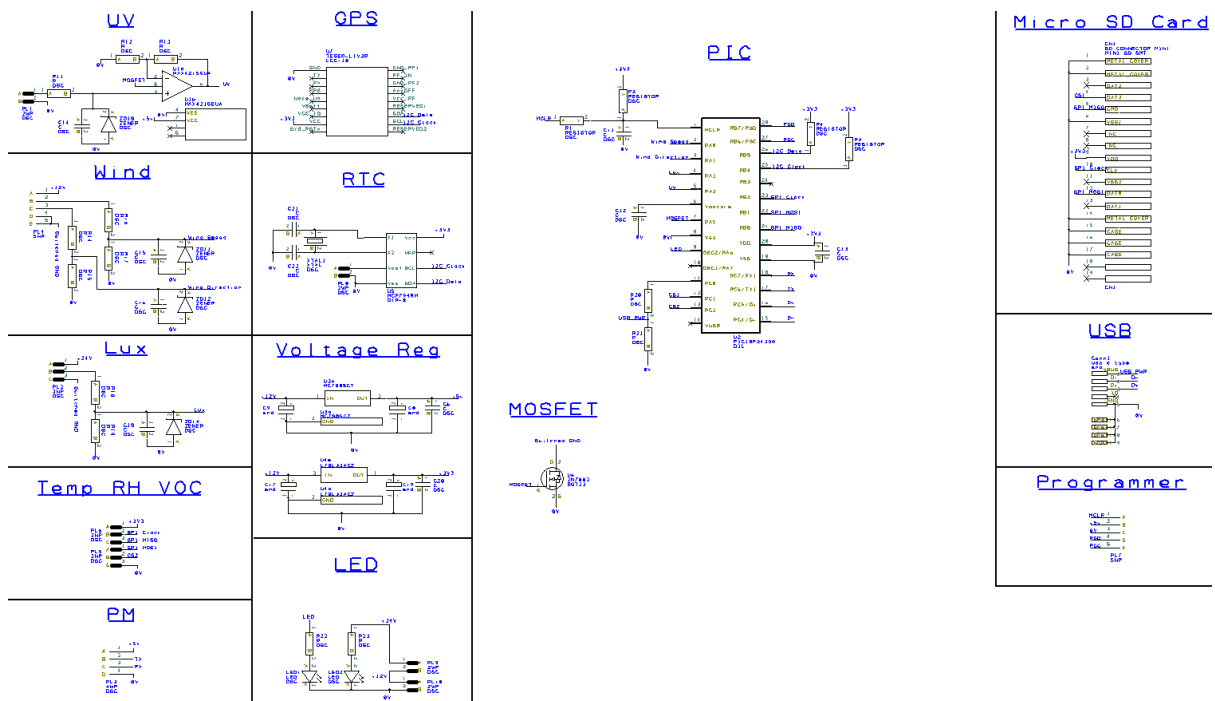


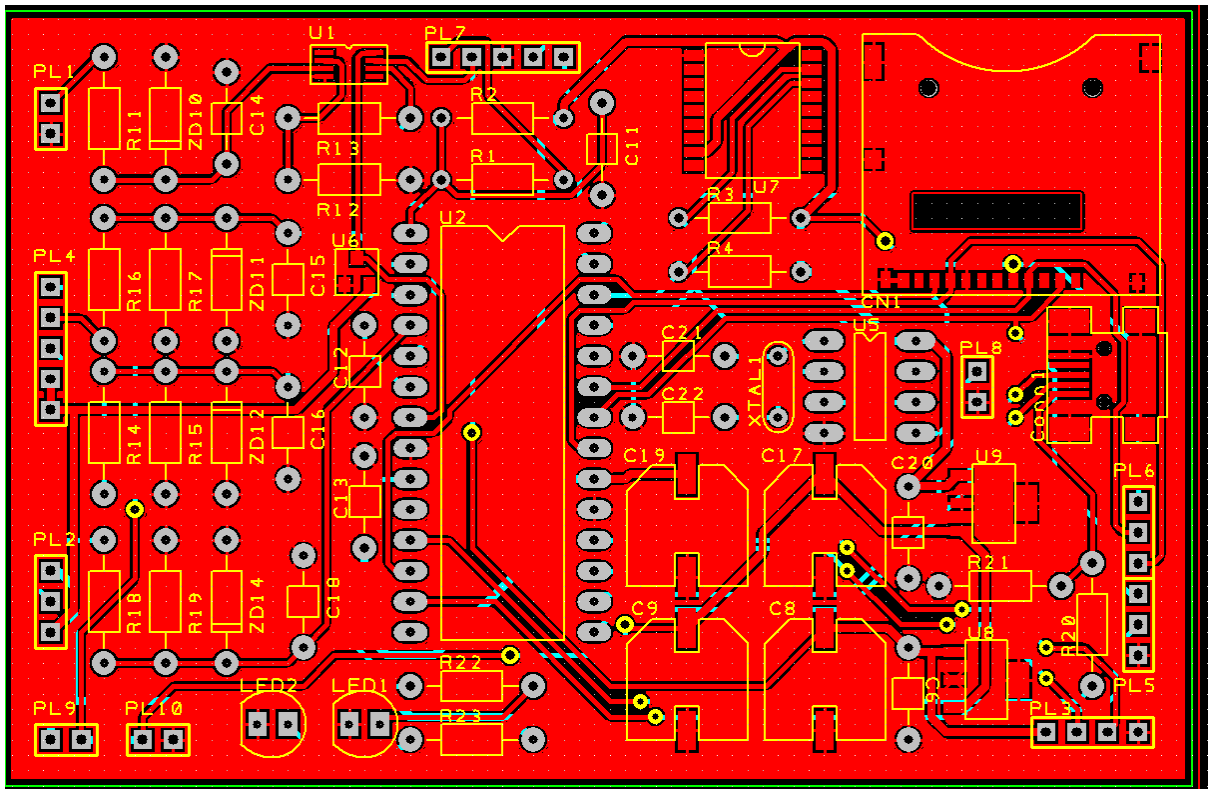
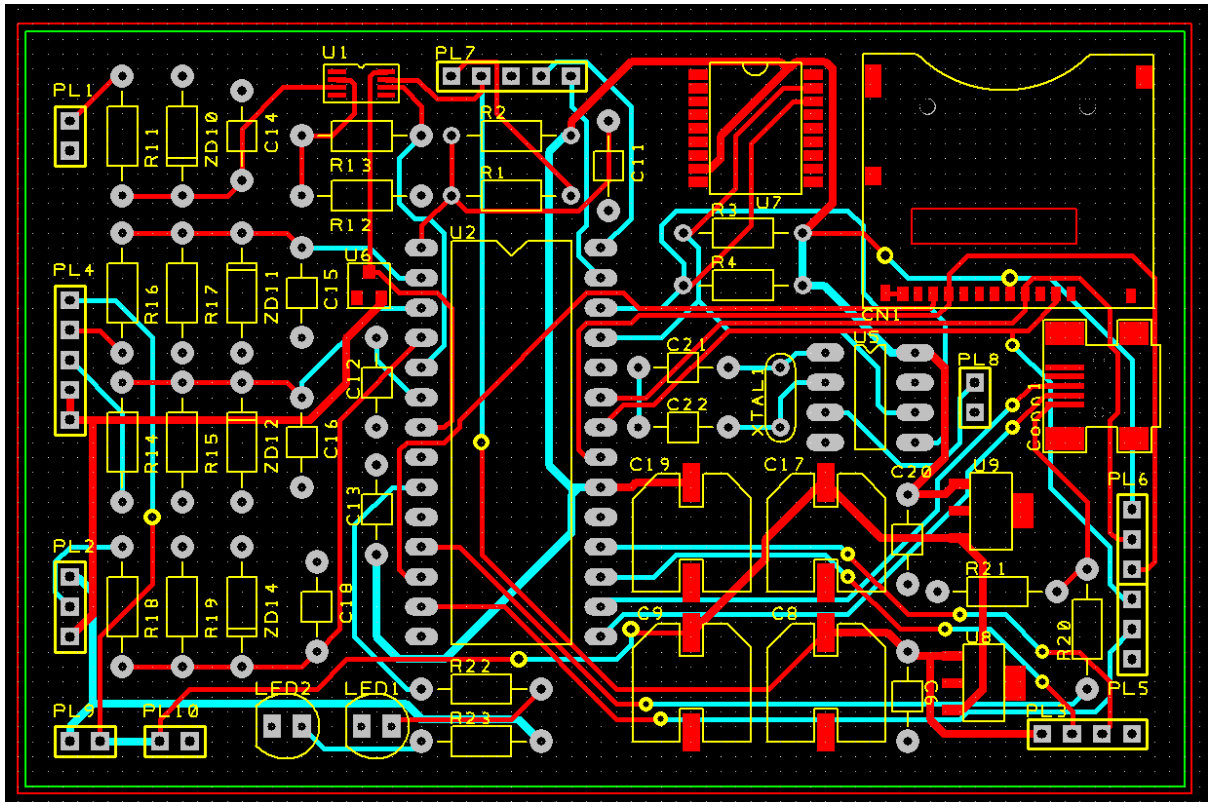
The GPS is powered by 3.3V and uses I2C to communicate with the PIC.



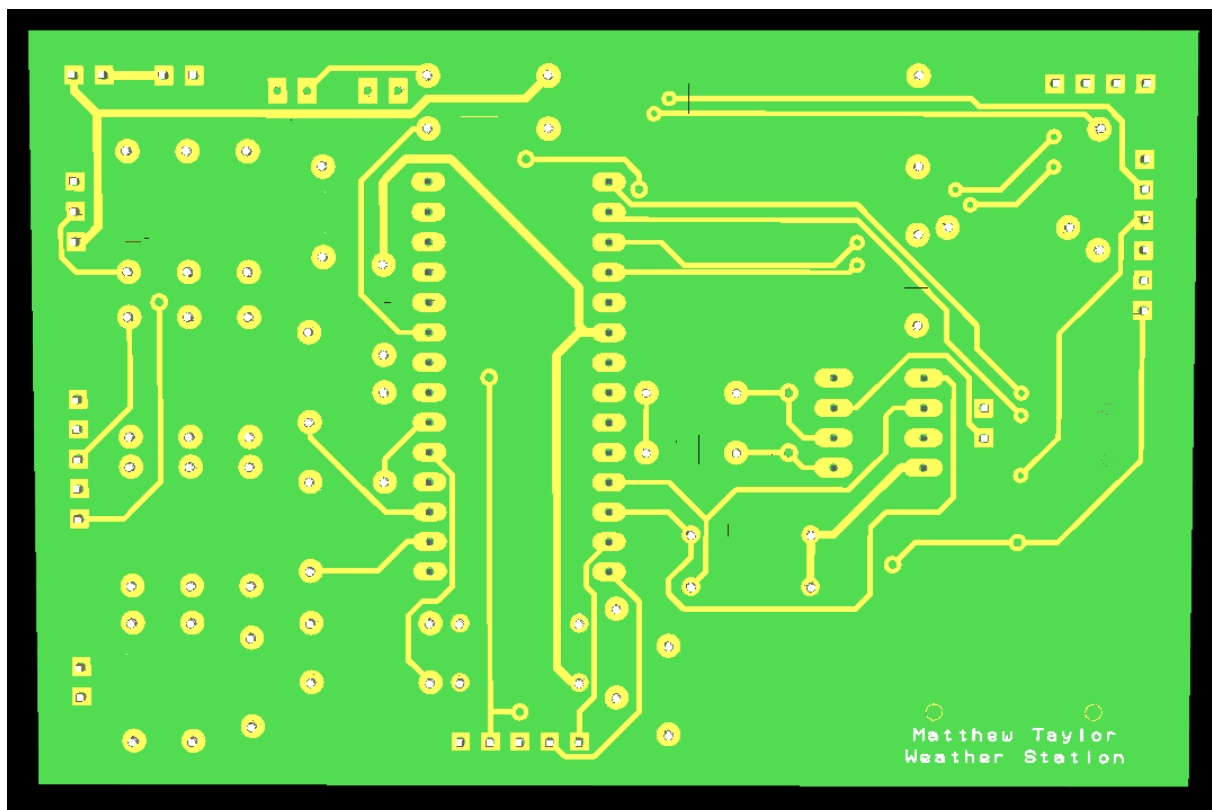
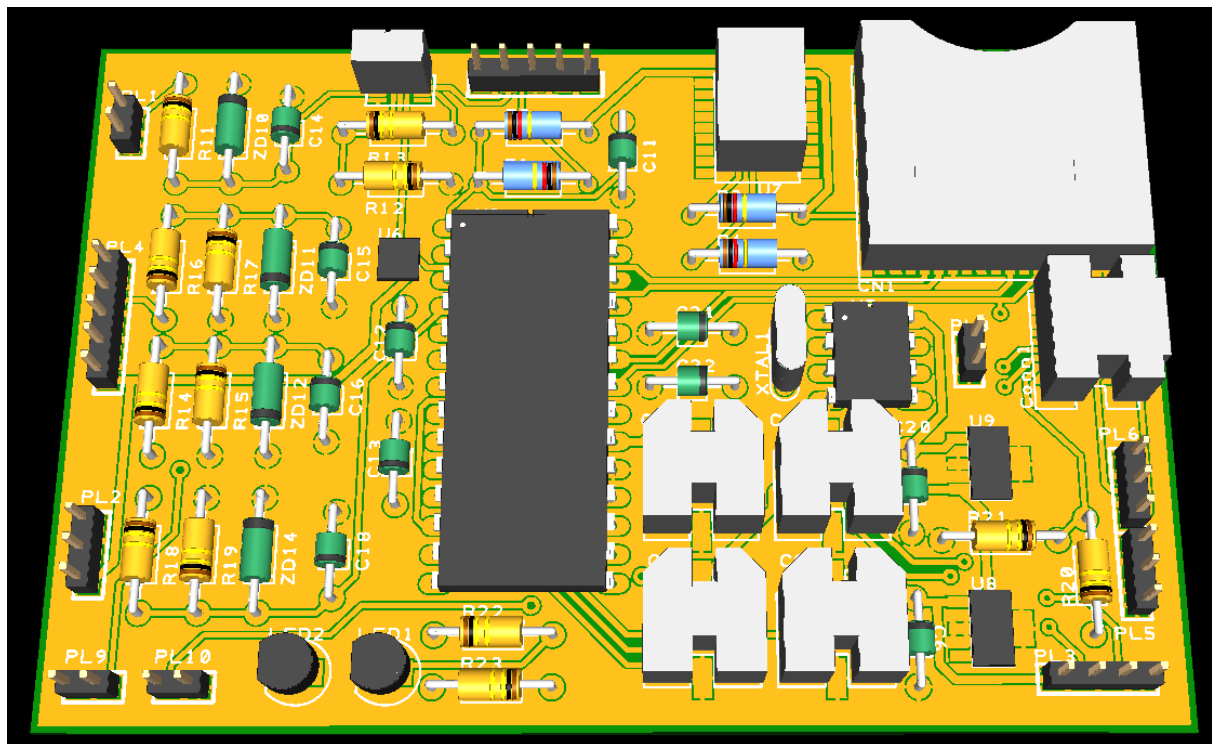
Easy-PC

To design the PCB I redrew the schematic in Easy-PC. I then placed the components on a PCB keeping connected parts near each other. I then routed the connections, then finally I created a copper pour to connect the 0V pins.



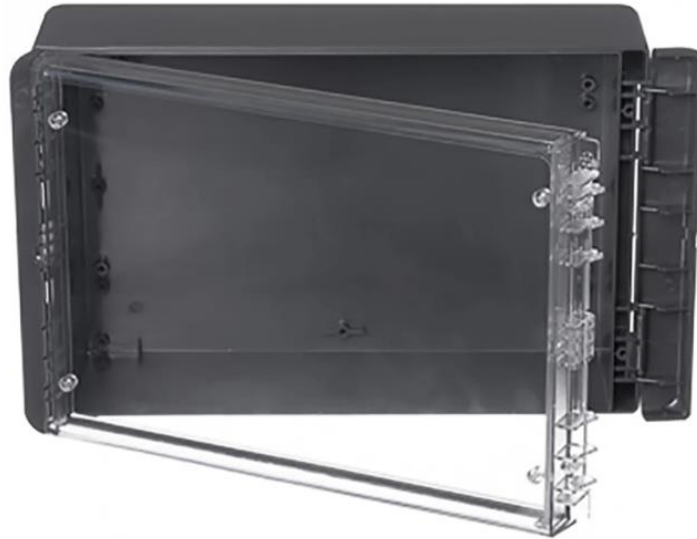


3D model

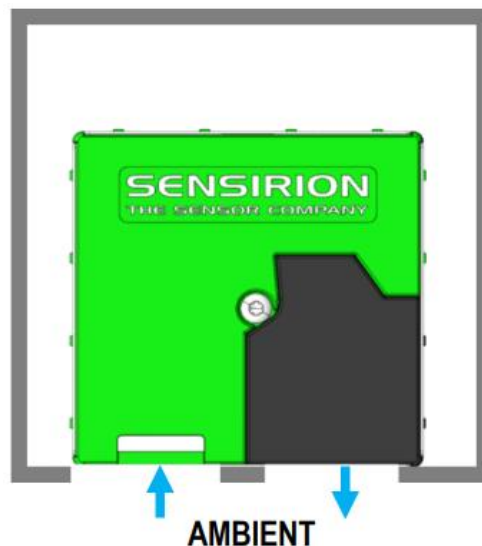


ENCLOSURE

I would base the weather station around the enclosure. I choose the Bocube Series by Bopla, and it is a Polycarbonate IP68 rated enclosure.



The PM sensor would be placed facing the bottom of the enclosure with a cut-out for the intake and exhaust, as recommended by the manufacturer in their diagram. The BME680 temperature/RH/VOC sensor would be placed next to the PM sensor inlet facing the bottom of the enclosure in the ambient air.



I would attach the wind anemometer and UV sensor to the top of the enclosure and I would attach the LUX sensor to the side of the enclosure. The wires for each of the sensor terminate inside the enclosure, so I would solder the wires directly to the PCB.

The batteries can be placed in the bottom on the enclosure and the PCB can be mounted to the rear.

The enclosure would require a clamp to be attached to the back so that it can be mounted on a pole or tripod.

NON-VOLATILE MEMORY

The specification of the design calls for the station to log the weather conditions for a 14 day period. The data needs to be stored locally before it can be retrieved via USB at the end of the test period. The size of the data prevents the use of the PICs built-in EEPROM, so I will use an SD card.

The BME680 uses serial communication, and on instruction will return the contents of a part of the register. The temperature and humidity each have 16 bits in the register and they are saved every minute. The VOC register is 10 bits and saved every 10 minutes.

$$\begin{aligned} \text{temp and RH memory} &= 4 \text{ bytes} * 20,160 \text{ (minutes in 14 days)} \\ \text{temp and RH memory} &= 80,640 \text{ bytes} \end{aligned}$$

$$\begin{aligned} \text{VOC memory} &= 10 \text{ bits} * 2016 \text{ (number of 10 min increments in 14 days)} \\ \text{VOC memory} &= 2520 \text{ bytes} \end{aligned}$$

The wind anemometer has two analogue outputs each connected to a 10-bit ADC. And both parameters are measured every 10 seconds. As the ADC is 10-bit, each reading will fit within 2 bytes.

$$\begin{aligned} \text{wind memory} &= 4 \text{ bytes} * 120960 \text{ (number of 10 second increments in 14 days)} \\ \text{wind memory} &= 483,840 \text{ bytes} \end{aligned}$$

The Particulate sensor uses serial communication to send the data, and stores the most recent readings in 39 bytes on the register. This includes the mass concentration and particle count for each of the four sizes of PM measured, as well as 4 bytes for the average particle size. I will save all the data available every 10 minutes.

$$\begin{aligned} \text{PM memory} &= 39 \text{ bytes} * 2016 \text{ (number of 10 min increments in 14 days)} \\ \text{PM memory} &= 78624 \text{ bytes} \end{aligned}$$

The brightness sensor is an analogue signal and connected to a 10-bit ADC. each reading will fit within 2 bytes.

$$\begin{aligned} \text{brightness memory} &= 2 \text{ bytes} * 2016 \text{ (number of 10 min increments in 14 days)} \\ \text{brightness memory} &= 4032 \text{ bytes} \end{aligned}$$

The UV sensor is an analogue signal and connected to a 10-bit ADC. each reading will fit within 2 bytes.

$$\begin{aligned} \text{UV memory} &= 2 \text{ bytes} * 2016 \text{ (number of 10 min increments in 14 days)} \\ \text{UV memory} &= 4032 \text{ bytes} \end{aligned}$$

The GPS location is recorded once per day, The data is 180 bits.

$$\begin{aligned} \text{GPS data} &= 180 \text{ bits} * 14 \text{ (number of days)} \\ \text{GPS data} &= 32 \text{ bytes} \end{aligned}$$

Device	Data Size
Temperature and Humidity	80,640 bytes
VOC	2,520 bytes
wind	483,840 bytes
PM	78,624 bytes
Brightness	4,032 bytes
UV	4,032 bytes
GPS	32 bytes

Total: 653.72 KB

COST

The total cost of the unit is £4,384.48.

description	manufacturer	manufacturer part no	location	price	qty	total price
Wind speed + direction	Windsonic	Windsonic 75	PL4	£1,029.00	1	£1,029.00
Brightness	S + S	PHOTASGARD AHKF-U	PL2	£95.98	1	£95.98
Ultraviolet	Kipp and Zonen	CUV 5	PL1	£3,023.00	1	£3,023.00
Particulate	Sensirion	SPS30	PL3	£47.04	1	£47.04
Temp/RH/VOC	Bosch	BME680	PL5,PL6	£11.71	1	£11.71
SD Card	Samsung	MMBTF04GWBCA-QME00		£2.87	1	£2.87
Enclosure	Bopla Bocube	96026334		£68.30	1	£68.30
Battery 12V	Yuasa	NP7-12	PL9, PL10	£23.26	2	£46.52
Battery 3.7V	OVERLANDER	2543	PL8	£5.70	1	£5.70
PCB	JLCPCB			£18.39	1	£18.39
PIC	Microchip	PIC18F24J50	U2	£2.36	1	£2.36
Green LED	Broadcom	HLMP-4740	LED1	£0.55	1	£0.55
Red LED	Broadcom	HLMP-K150	LED2	£0.56	1	£0.56
MOSFET	Onsemi	2N7002	U6	£0.40	1	£0.40
3.3 V Regulator	Infineon	TLE42744GSV33HTMA1	U4	£1.99	1	£1.99
5 V Regulator	Microchip	MCP1790-5002E/DB	U3	£1.05	1	£1.05
op amp (for UV)	Maxim	MAX4236BESA+	U1	£2.59	1	£2.59
RTC	Microchip	MCP7940M-I/P	U5	£0.99	1	£0.99
USB connector	Molex	47590-0001	CONN1	£0.72	1	£0.72
SD card holder	WURTH ELEKTRONIK	6.93061E+11	CN1	£4.47	1	£4.47
GPS	Stmicroelectronics	TESEO-LIV3R	U7	£12.28	1	£12.28
20K5 RES	Multicomp Pro	MCMF0W4DF2052A50	R18	£0.13	1	£0.13
10K RES	Multicomp Pro	MCRE000049	R2, R3, R4, R15, R17, R19, R21	£0.04	7	£0.28
5K23 RES	VISHAY	MRS25000C5231FCT00	R14, R16, R20	£0.12	3	£0.36
66K5 RES	VISHAY	MRS25000C6652FCT00	R12	£0.20	1	£0.20

97K6 RES	VISHAY	MRS25000C9762FCT00	R13	£0.12	1	£0.12
30R RES	Multicomp Pro	MCMF006FF300JA50	R11	£0.03	1	£0.03
10K5 RES	Multicomp Pro	MCMF0W4DF1052A50	R23	£0.07	1	£0.07
700R RES	TE Connectivity	LR0204F750R	R22	£0.01	1	£0.01
470R RES	YAGEO	CFR-25JB-52-470R	R1	£0.05	1	£0.05
1uF CAP	KEMET	C410C105K3R5TA	C14, C15, C16, C18	£0.34	4	£1.36
100nF CAP	KEMET	C412C104K5R5TA7200	C11, C13, C23	£0.16	3	£0.48
1nF CAP	KEMET	C410C102K1R5TA	C6, C20	£0.38	2	£0.76
1uF Electrolytic CAP	VISHAY	MAL215371108E3	C8, C9, C17, C19	£0.62	4	£2.48
6pF CAP	VISHAY	D689C20C0HH63L2R	C21, C22	£0.20	2	£0.40
10uF CAP	TDK	FG26X7R1E106KRT06	C12	£0.42	1	£0.42
Zener Diode (3.6V)	Multicomp Pro	1N4729A	ZD10, ZD11, ZD12, ZD14	£0.13	4	£0.52
32.768kHz crystal	EuroQuartz	MH32768B	XTAL1	£0.34	1	£0.34
					Total	£4,384.48

CONCLUSION

After finishing my design of a weather station, I have a few improvements that could be made. A rain gauge could be included like in the Vantage Pro 2, EnviroTrack, and IntelliSense stations.

They also included An air pressure sensor which is helpful for weather forecasting. Bosch make a component like the BME680 that I used for VOC, called the BME280, that measures air pressure. Another simple change could be to include live updates of the measurements over USB or wirelessly. The USB could be implemented with no additional hardware.

The price and function offered by the UV sensor isn't justified for an amateur weather station as laid out in the brief.

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