

ESD 2 Assignment

by Cameron Fitze

Submission date: 15-Dec-2024 08:53PM (UTC+0000)

Submission ID: 246210867

File name: 32803_Cameron_Fitze_ESD_2_Assignment_523685_1292667195.docx (3.76M)

Word count: 4032

Character count: 21888

Electronics Systems Design
Assignment – Cameron Paul Fitze
2111737

Cameron Paul Fitze

University of Wales Trinity St David

Course Number:

Course Name: BEng Embedded Electronic Systems



Abstract

Portable weather stations are a way of gathering weather measurements in the field. There are a range of portable weather stations from cheap amateur ones to professional field ones used by meteorological institutions.

There are a range of sensors involved in this assignment, and because some could be combined, there are a total of 7 sensors for 7 environmental parameters.

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1. Introduction

1.1 Aim

The aim of this assignment is to design a portable weather measurement station that will collect various environmental parameters over a 14-day period.

There are following parameters will be measured over a 14-day period:

1. Temperature
2. Humidity
3. Wind Speed
4. Wind direction
5. Air borne particle count
6. Sunlight brightness
7. UV levels
8. GPS position
9. Volatile Organic Compound (VOC) level

1.2 Report Layout

This report details the process of building a portable weather station.

The sections in this report are as follows:

1. Literature Study (see section **Error! Reference source not found.**)
2. Microcontroller Considerations (see section **Error! Reference source not found.**)
3. Hardware Considerations (see section **Error! Reference source not found.**)
4. Circuit and PCB Designs (see section **Error! Reference source not found.**)
5. Prototype build costs (see section **Error! Reference source not found.**)
6. Suggested improvements of specifications based on literature review
7. Conclusions (see section 0)
8. Recommendations (see section 5)

2. Literature Review of Portable Weather Measurement Systems

This section explores existing commercial of the shelf (COTS) devices used for the purpose of gathering environmental or climatic measurements that complement the construction of a weather station.

A portable weather measurement system leverages non-static weather instrumentation, which can be moved to various locations in order to obtain local weather measurements. A variety of sensors input into the circuitry of the system, which provides the electronic components to facilitate the signals coming from each sensor and provide the end goal of a weather reading to the user.

There are a range of portable weather stations on the market, ranging from simple domestic ones to ones for professional applications. Table 1 shows a range of COTS weather stations ranging from cheap domestic use ones, the TFA Dostmann and the Bresser Tenden, to expensive ones for professional uses, the Davis Wireless Vantage and the Spectrum Watchdog.

The main difference can be seen in the range of measurements on offer: the cheaper weather stations tend only to offer temperature and humidity (maybe air pressure), whereas the more expensive options offer those measurements plus wind speed and direction, UV, light sensing, amongst offer measurements.

Weather station	Image	Measurements	Price (£)	Reference
TFA Dostmann weather forecaster		Temperature, humidity, weather forecast	16.96	Link A
Bresser Tendencia FSX Weather station		Temperature, humidity, moon phases, ice alert, air pressure	55.99	Link B
Davis Wireless Vantage Vue Weather Station with WeatherLink Console 6242UK		Barometric Pressure, Dew Point, Humidity, Rainfall, Temperature, Wind	599.95	Link C

		Direction, Wind Spee		
Spectrum WatchDog 3240 WiFi/Cellular Weather Station		Temperature, humidity, rainfall, wind speed, wind direction, light sensor, UV, leaf wetness	2,664	Link D

Table 1 - Portable Weather Stations

2.1 Sensor Selection

A variety of sensors that provide environmental measurements to weather stations, providing a visual to the user of the current climatic conditions in the locale of the weather station.

It is important to explore existing weather measurement sensors or instruments on the market in order to identify the following parameters:

- What applications they are used for – what measurements they can provide
- Benefits and disadvantages
- Connector Types (plus any necessary adapters)
- Power requirements

The following sub sections outline the sensor study that was undertaken as part of this project and identify suitable sensors on the back of this study.

2.1.1 Wind Speed

Table 2 shows the results of the COTS study for wind speed measurement instruments. The most suitable sensor identified was the **rotating cup**. This is due to its simplicity, low cost, and the fact that it does not need to be positioned in the direction of the wind for an accurate measurement.

However, further COTS research has identified sensors that provide multiple weather measurements. Reducing the number of sensor inputs into the system will simplify its construction. Section 0, detailing the wind direction COTS study, identifies sensors that gather multiple measurement parameters, and thus a conclusion for a wind speed sensor will not be made within this sub section.

Wind Speed					
Sensor Types	Sensor Image	Benefits	Disadvantages	References	
Rotating: Cup		Simple Does not need to be held in the direction of the wind	Only measures air flow speed	Link 1	Link 2
Rotating: Windmill/ anemometer		Does air flow velocity, relative humidity and air temperature	More expensive	Link 3	
Wind Pressure: Pitot tube		Good for higher wind speed applications (due to pressure differences not working at lower speeds) like measuring speed of airplanes flying	not good at lower wind speeds	Link 4	
Thermal: Hot wire		No moving parts so durable, and suitable for low-speed applications, lower cost and good performance	Not really used for weather measurements, rather for measuring any unwanted air flows in buildings, for instance.	Link 6	

Table 2 - Wind speed sensor type selection

2.1.2 Wind Direction

Error! Reference source not found. shows the COTS study results for wind direction sensors. The most suitable sensor identified was the **Wind Vane**. This is due to it providing both wind speed and direction measurements. This is a sensor that is used in maritime applications, as per the reference. The only disadvantage is cost, which is likely amplified by its maritime application, and it will also require a NMEA 0183 to USB adaptor, listed in the table, to interface it with the PIC.

Sensor Types					Sensor Image	Benefits	Disadvantages	References
Wind Vane		Does air flow velocity and direction	Costly	Link 7				
Ultrasonic: Ultrasonic	 	Wind speed and direction, no moving parts so very durable	Complex and costly	Link 5				
Windsock		Wind speed and direction, very durable	Low cost, simple	Link 8				

Sensor Types	Sensor Image	Benefits	Disadvantages	References	Connector Type
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Capacitive		Wide measurement range Low cost stable results little maintenance	Distance issues between circuit and sensor Loss of accuracy below 5% humidity	Link 9	Through hole
Resistive		low cost (although appears to be higher than capacitive) small size distance between circuit and sensor can be large (unlike capacitive), therefore could be used for long range applications	sensitive to chemical vapours readings may lose accuracy if used with water soluble products	Link 10	Through hole
Thermal		Durable Suitable for high temp and high corrosive high granularity	uses nitrogen, so exposure to gas different to this could affect readings	Link 11	Through hole
Resistive (Combination of Temperature and Humidity) - Amphenol Advanced Sensors T		As per resistive component mentioned plus: Provides both temperature and humidity measurements	As per the resistive component mentioned	Link 12	I2C

Table 3 - Humidity Sensor Type Selection

2.1.4 Temperature Sensor

Table 4 shows the COTS study for the temperature sensor type selection. The most suitable sensor identified was the **thermocouple** as it has a wide temperature range compared to the other sensors. This sensor uses a **type K** connector. However, the section detailing the humidity sensor identified a sensor that could provide both temperature and humidity readings, the **resistive (Amphenol Advanced Sensors)**.

Sensor Types	Sensor Image	Benefits	Disadvantages	References	Connector Type
Thermocouples		Self-powered require no excitation wide temp range	temp measurements can be difficult susceptible to noise	Link 13	Type K Thermocouple connector

		quick response times			
Resistance Temperature Detector		wide temp range linear response	Requires SIGNAL CONDITIONING as they are slow to respond in changes to temperature than thermocouples unlike thermocouples, they require excitation	Link 14	Class B Thermocouple connector
Thermistors		small size high sensitivity	non-linear therefore requires significant correction to read correct data narrow temp range	Link 15	Through hole
Semiconductor-based ICs		flexible to implement very small	narrow temp range	Link 16	Surface mount

Table 4 - Temperature Sensor Type Selection

2.1.5 UV Sensor

Table 5 shows the COTS study for the UV sensor type selection. The most suitable sensor identified was the **Pyranometer** as it does not require to be aimed in a particular direction to acquire accurate readings and it is designed for meteorological measurements. This sensor uses a **type K** connector.

Sensor Types	Sensor Image	Benefits	Disadvantages	References	Connector Type
Photodiode		good linearity very sensitive to light low noise	•small active area •needs to offset voltage •amplification required at lower irradiance	Link 17	
Photoresistor			•Less accurate than photodiode •only really used to determine whether light is on or off instead of actual levels	Link 18	
Albedometer		accurate versatile application low cost	its own shadow can affect readings	Link 19	
Pyrheliometer		low power consumption wide voltage range	must be aimed directly at the sun	Link 20	

		rigid and stable			
Pyranometer		mainly used for meteorology as measures UV received from all directions	not as accurate as Pyrheliometer Link 22	Link 21	Positive and negative wire

Table 5 - UV Sensor Type Selection

2.1.6 Sun Light Sensor

Table 6 shows the COTS study for the sun light sensor type selection. The most suitable sensor type identified was the **Phototransistor**. This is due to it having high sensitivity, high output current, and a linear response range. It is a **through-hole** component, so will be connected straight to the circuit board.

Sensor Types	Sensor Image	Benefits	Disadvantages	References	Connector Type
Photoresistor			• Less accurate than photodiode • only really used to determine whether light is on or off instead of	Link 22	

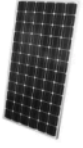
			actual leavels		
Phototransistor		•more sensitive than photodiode •higher output current •linear response range is lower than photodiode	•low output response	Link 23	Through hole
Photodiode		•Fast output response • high linear response range	- less sensitive than phototransistor •allows for low current compared to phototransistor	Link 24	
Photovoltaic		•Various mounting options	• Various toxic chemicals in the production process such as arsenic and cadmium	Link 25	

Table 6 - Sun Light Sensor Type Selection

2.1.7 Airborne Particle Count

Table 7 shows the COTS study for the Airborne Particle Count sensor type selection. As shown, there is only one sensor type for this application, the **laser**. This sensor comes with a **USB** interface for connection to the circuit.

Sensor Types	Sensor Image	Benefits	Disadvantages	References	Connector Type
Laser		N/A as only a laser sensor is available for air borne particle counter	N/A	Link 26	USB
Laser		As above	N/A	Link 26.1	USB

Table 7 - Airborne Particle Count Sensor Type Selection

2.1.8 GPS

Table 8 shows the COTS study for the GPS sensor type selection. There is only one type of sensor that detects GPS, a **GPS receiver**. The one chosen in the table uses a **I2C** interface.

Sensor Types	Sensor Image	Benefits	Disadvantages	References	Connector Type/ Interface
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GPS receiver		N/A	N/A	Link 27	I2C
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Table 8 - GPS Sensor Type Selection

2.1.9 VOC Sensor

Table 9 shows the COTS study for the VOC sensor type selection. The most suitable sensor identified was the **photoacoustic** infrared, specifically the SparkFun Photoacoustic Spectroscopy CO2 sensor. This sensor has high sensitivity and can be easily integrated into the circuit as it is a chip. It uses **I2C, UART, and Pulse Width Modulation (PWM)** interfaces.

Sensor Types	Sensor Image	Benefits	Disadvantages	References	Connector type/ Interface
Photoionisation Detector		•High precision •Non-destructive detector •Strong anti-interference	•Can lose accuracy •Humidity can affect readings •Does not measure all gases	Link 28	
Metal-oxide semiconductor (MOS)		•High sensitivity •High compatability •Low cost	•Sensitive to environmental factors •Limited useful lifespan •Sensor readings can drift over time	Link 29	
Flame Ionisation detector		•Low detection threshold (high sensitivity) •Low cost •Reliable	•Limited dynamic linear range compared to other sensors •Does not provide granular	Link 30	

			information about VOC		
Photo acoustic infrared		Smaller Highly sensitive	Susceptible to noise	Link 31	I2C, UART, PWM

Table 9 - VOC Sensor Type Selection

There are a total of 9 sensors required for this project. However, as the temperature and humidity, and winds speed and wind direction sensors are being combined, this will bring the total number of sensors down to 7.

3. Microcontroller Selection

The requirements of the microcontroller were derived from Table 10. As shown in that table, the requirements are as follows:

- Total number of sensors: 7
- Connector interfaces/ protocols:
 - I2C: 2
 - UART: 1
 - USB: 1
 - I/O Ports: 3
- Max voltage requirement <30V, although signal conditioners will be used on all sensors that output over 5V. The total number of sensors that meet that requirement are 3.

Parameter	No. Sensors	Connector/ Interface	voltage output	Voltage input	Signal Conditioning?
Temp	1	i2c	3V	3.3VDC	N
Humidity					
Wind speed	1	NMEA0183 (normal port input on chip)	12V/24V DC	12v/24v DC	Y
Wind direction					
Air borne particle count	1	USB	?	AC 220V	Y
Sunlight brightness	1	through hole (normal port input on chip)	N/A	N/A	N
UV levels	1	type K (normal port input on chip)		8-30V dc	Y
GPS position	1	i2c	3.3-5v	3.3-5v	N
VOC level	1	UART	3.3v	3.3v	N
TOTAL	7	N/A	N/A	N/A	3

Table 10 - Sensor Input/ circuit Requirements for Microcontroller Selection

Additionally, the following specifications were required:

- Pin count = 28
- ADC input = >2

Once the requirements were identified, the next step is to identify a suitable microcontroller that meets the requirements in Table 10 and the list above. The microcontroller selection utilised a parametric search, which identifies a range of suitable microcontrollers based on a variety of required specifications.

The parametric search resulted in a small range of suitable PICs for this project. The one chosen was PIC18F25J50. This was chosen as it meets all the requirements set out and the PIC18F range is a familiar product.

The specifications of this PIC are as follows:

- Program Memory size: 32KB
- RAM: 3.8KB
- Data EEPROM (bytes): 0
- ADC Channels: 10
- SPI: 2
- I2C: 2
- Operating Voltage range: 2 – 3.6V
- Pin count: 28

This PIC does meet the requirements for the sensors as it has 2 SPI and 2 I2C interfaces. The negative of this PIC it has no EEPROM storage, so a Secure Digital (SD) card will be essential in capturing data from the sensors.

Additionally, the operating voltage is 2 – 3.6V. The three sensors that operate above that will have signal conditioning to bring their voltage down to the operating range of this PIC. All other sensors have an operating voltage of <3.3V.

4. Task 3

4.1 A suitable package (casing) for the system that is both portable and suitable for the environment

Weather station casing has to be suitable as incorrect measurements could be acquired if not. For instance, a temperature sensor has to be shielded from direct sunlight as this significantly alters the temperature readings. Additionally, a wind vane needs to be exposed to acquire its readings.

Table 11 outlines suitable casing, if required, against each sensor. As show, the temperature sensor is the one that requires its own casing, the wind vane has an external mount, and all other sensors can be external, with any electronics housed in a Peli Case.

Parameter	Casing type	Suitable Casing Image	Link
Temp	Shielded		Link
Humidity			
Wind speed	External Mount	The sensor chosen has a mount, so this should be attached in location	N/A
Wind direction			
Air borne particle count	Shielded	N/A	N/A
Sunlight brightness	External	N/A	N/A
UV levels	External	N/A	N/A
GPS position	External/ Shielded	N/A	N/A
VOC level	External/ Shielded	N/A	N/A

Table 11 - Suitable Casing Type for Each Sensor

Figure 1 shows the Peli Case that has been chosen for this weather station.



Figure 1 - Peli Case for Weather Station [1]

Link: https://www.casesuk.com/explorer-cases/5833.BE.html?gad_source=1&gclid=EAlaIqobChMI9d7CyuCpigMVhbCDBx1dEymaEAQYBiABEgK5mfD_BwE

This Peli Case has the size to house all of the electronics, and is resistance to various environmental conditions (for instance it has a temperature rating of -33c to 90c).

4.2 The size of the storage (non-volatile) memory needed

The collected data will be stored to non-volatile memory, which may be externally read and cleared when connected to a computer via USB.

The type of non-volatile memory chosen for this is an SD card. The storage requirements of the SD card are approximately 10KB per 14 days. The derivation of this figure can be seen in Figure 2.

Parameter	Value	Connector type	connector / interface	voltage output	voltage input	signal, control I/O	data per reading			readings per hour	total bytes per hour	total bytes per day	
Temp	Temperature	Rotating Cup	1	IR	2V	3.3VDC	N	2			6	192	
Humidity	Humidity	Rotating Cup	1	IR	2V	3.3VDC	N	2			6	192	
Wind speed	Wind speed	Rotating Cup	1	IR	2V	3.3VDC	N	2			6	192	
Wind direction	Wind direction	Rotating Cup	1	IR	2V	3.3VDC	N	2			6	192	
45° down speed to count	45° down speed to count	Rotating Cup	1	IR	2V	3.3VDC	N	2			6	192	
Barometric pressure	Barometric pressure	Rotating Cup	1	IR	2V	3.3VDC	N	2			6	192	
Light intensity	Light intensity	Rotating Cup	1	IR	2V	3.3VDC	N	2			6	192	
Cloud cover	Cloud cover	Rotating Cup	1	IR	2V	3.3VDC	N	2			6	192	
GPS location	GPS location	Rotating Cup	1	IR	2V	3.3VDC	N	2			6	192	
GPS speed	GPS speed	Rotating Cup	1	IR	2V	3.3VDC	N	2			6	192	
GPS altitude	GPS altitude	Rotating Cup	1	IR	2V	3.3VDC	N	2			6	192	
											total readings per day	126	4032
											total readings per week	882	28224
											total readings per 2 weeks (14 days)	1764	56448
											total data captured over 14 days (14 days)	5040	161280

Figure 2 - Weather Station Data Usage over 14 days

This appears to be a very low number, and according to Ambient Weather the average data used over a month for their weather stations is 76MB [2]. However, this is for a reading every 12 seconds, where as my is storing readings every 15 minutes.

Plenty of SD cards will meet these requirements as this is a very low amount of storage, so it should be cost effective to source one. The following one will be suitable for this project:

<https://www.mymemory.co.uk/mymemory-32gb-v30-pro-high-speed-sd-card-sdhc-uhs-1-u3-100mb-s.html>

This has a total storage of 32GB and a read speed of 100MB/S

4.3 The sensors required

See section 2.1.

4.4 Connector Specification and battery

Connectors

There are 7 sensors input signals for this circuit. The connectors for each sensor were identified in section 0.

Battery

A battery is required as this application is portable. Weather stations use a variety of power means, ranging from AA (as seen in the cheaper weather stations) to solar (as seen in the more expensive weather stations) with battery backup.

For this weather station, the power requirements need to be ascertained in order to source a suitable battery source. The maximum voltage that will be required is 12V.

Task 4 – PCB design and Circuit Schematic and block diagram

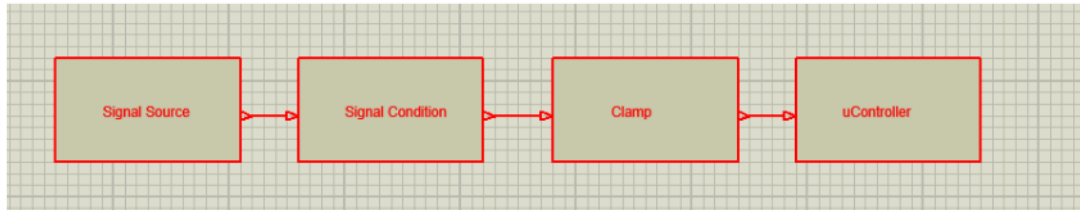


Figure 3 - Circuit Flow Block Diagram

All signal inputs require **signal clamps**, but only those with output voltages of >5V require **signal conditioning**. [3]

The circuit comprises of four main stages, which are described in the following subsections.

3.1 Signal Source

The **Signal Source** is provided from each of the sensor's outputs. There are 7 signal sources in this circuit providing the following signal source:

1. Wind speed and Wind direction
2. Humidity and temperature
3. UV
4. Sun light
5. Airborne particle count
6. GPS
7. VOC

3.2 Signal Conditioning [3]

The **Signal Conditioner** manipulates the signal to prepare it for the next stage. Sensors that collect mechanical data may incur corruption to their signal due to the mechanical forces exerted on the sensor as part of the data acquisition process.

Analogue signals especially require signal conditioning because analogue signals experience instability that can prove difficult for the DAQ system to process. This can result in erroneous readings for the DAQ system, which will erode its validity. Additionally, analogue signals experience a varying voltage range. Therefore, if signal conditioning is not done before the analogue-to-digital converter (ADC), this can essentially result in a mismatch in voltage between the sensor and the ADC.

Signal conditioning often employs a filter (low pass, high pass, band pass) to block any frequencies outside of the ADC's sampling range.

Not all of the sensor circuits will require signal conditioning. This is because some of their output voltages fall below 5V – with the >5V signal sources, the signal conditioner reduces that voltage. For this particular weather station, there will be a total of 3 signal conditioners, for the **wind vane**, **airborne particle count sensor**, and the **Pyranometer**. These all have power requirements of over 5V and therefore will need the voltage controlled to protect the chip.

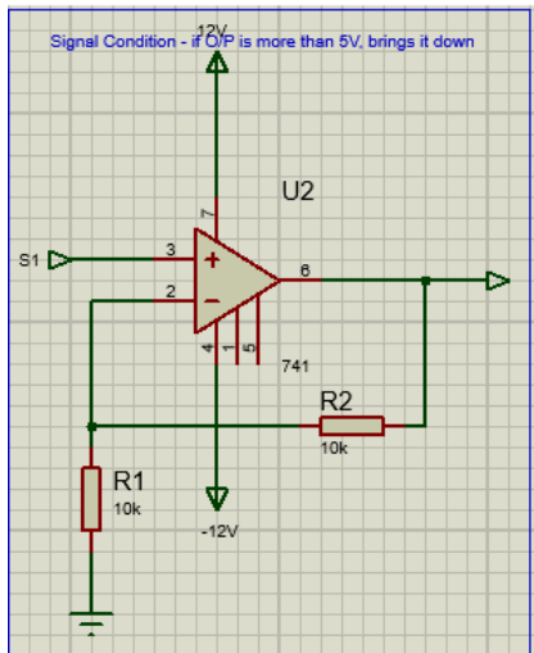


Figure 4 - Signal Conditioning Circuit

Figure 4 shows the signal conditioning circuit design on Proteus. The main component is the LM741 Op Amp, which takes the input signal and amplifies its power, producing an output signal with a voltage differing to that of the input signal voltage. The operating voltage of the 741 is up to 22V [4]. This is sufficient to facilitate the highest input voltage from the sensors, which is 6V from the gyroscope (see section **Error! Reference source not found.** for full details).

3.3 Signal Clamping [3]

The **Clamp** provides protection to the PIC against a high voltage input from the sensors. All sensor-to-IC circuits require a clamp.

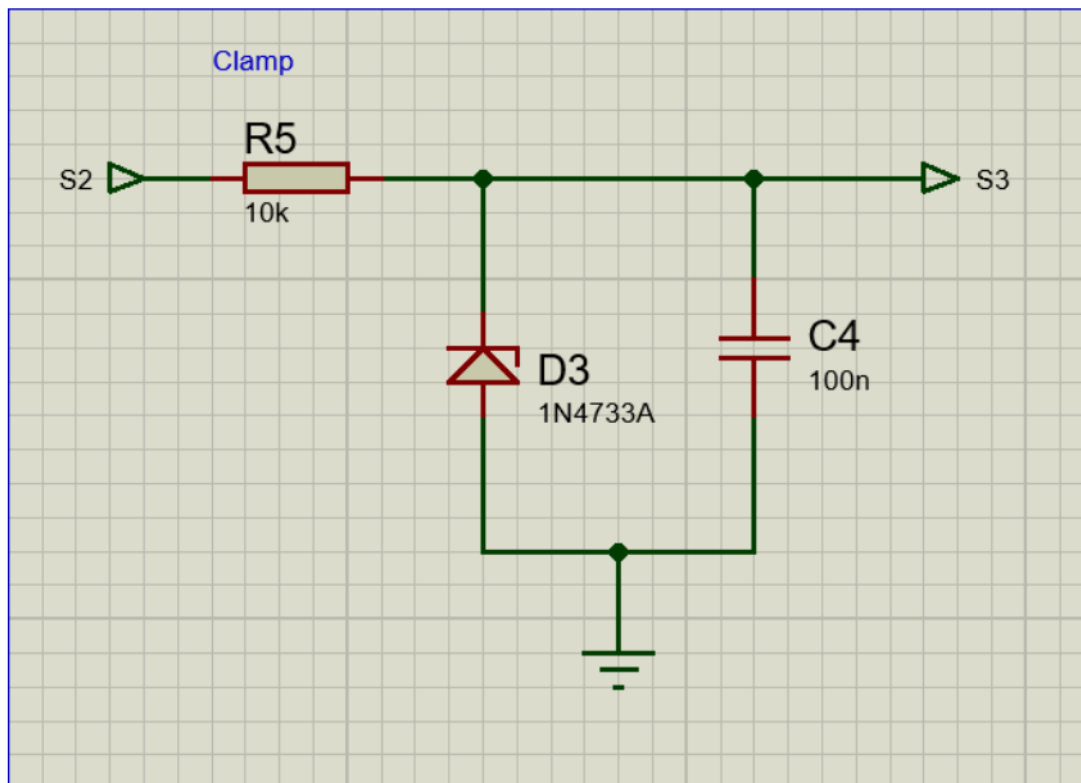


Figure 5 - Clamping Circuit

Alternatively, a Clamping Circuit integrated circuit (IC) can be used. These ICs, like the circuit above, protect the PIC from high voltage power spikes from the signal sources (sensors).

3.4 Controller

The **uController** is the PIC18F25J50 chip. This is described in section **Error! Reference source not found..**

3.5 Proteus Schematic

Figure 6 shows the weather station circuit schematic on Proteus (the file is attached separately as requested). This design adheres to the flow shown in Figure 3. With the 7 sensor signal sources on the left, then any required signal conditioning, followed by signal clamping, and finally the PIC, with SD card and USB connected as shown.

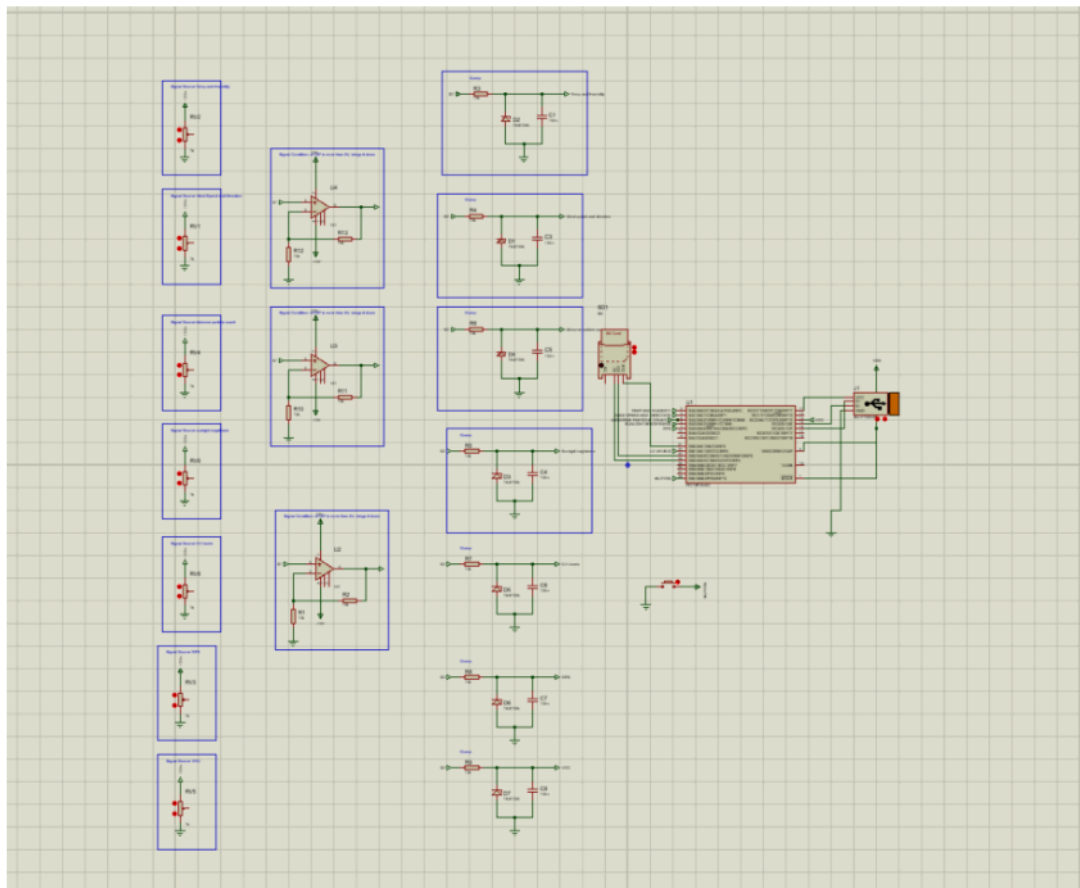


Figure 6 - Proteus Schematic

3.5 Easy PC Schematic

Figure 7 shows the Easy PC schematic for the weather station circuit. It has all constituent parts as described in section 0.

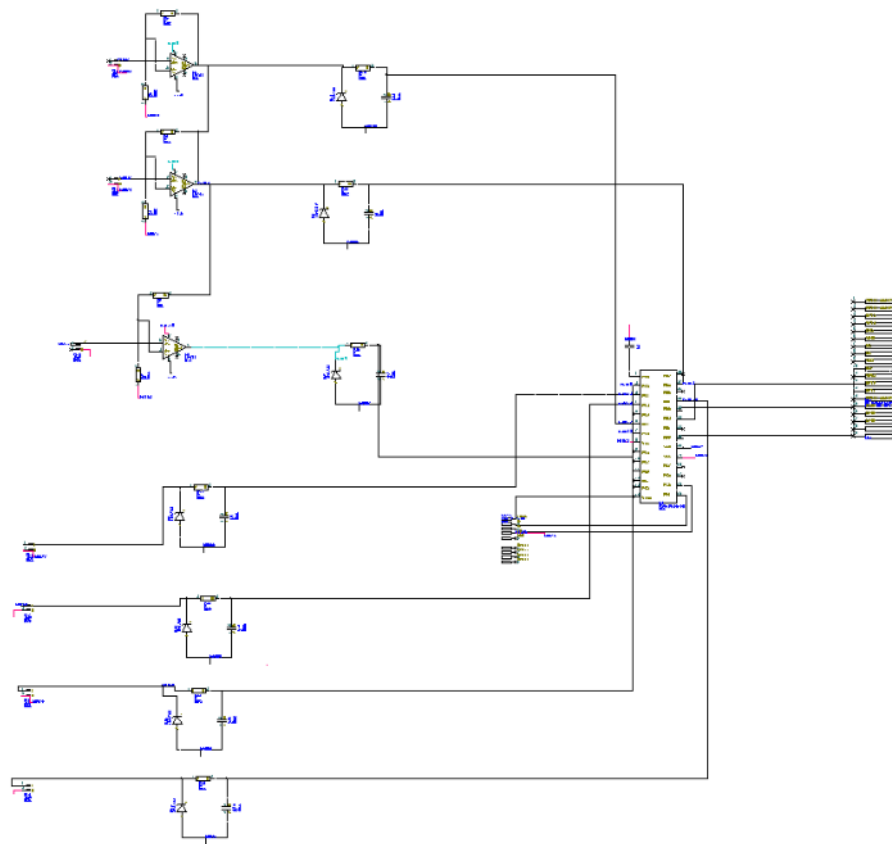


Figure 7 - Easy PC Schematic

3.6 Easy PC PCB

Figure 8 shows the Easy PC circuit schematic. This is a direct translation of the Easy PC Schematic.

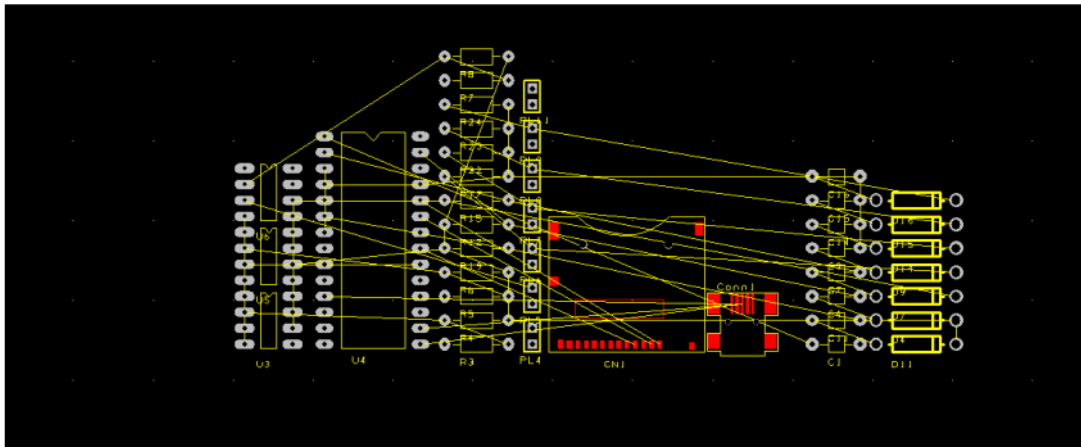


Figure 8 - Easy PC PCB

Task 6 – Prototype Build Costs

Item	Quantity	Price (£) (Incl. VAT)	Link
Wind speed and direction sensor	1	354.00	See section 0
Humidity and Temperature Sensor	1	37.00	See section 0
UV sensor	1	2,900.00	See section 0
Sunlight sensor	1	430.00	https://www.scientificsales.com/Kipp-Zonen-SP-Lite2-Pyranometer-p/sp2-lite.htm
Airborne particle count	1	3,615	See section 0
GPS	1	37.62	See section 0
VOC	1	56.40	See section 0
PIC18F25J50	1	4.20	Link
Temperature and humidity sensor Casing	1	14.03	See section 4.1 A suitable package (casing) for the system that is both portable and suitable for the environment0
Peli Case	1	291.65	See section 4.1 A suitable package (casing) for the system that is both portable and suitable for the environment0
SD Card	1	6.49	
Connectors	7	All chosen sensors include their respective connectors	

TOTAL		7,746.39	
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Table 12 - Bill of Materials

4. Conclusions

There are a large range of portable weather stations on the market ranging from small and cheap home stations to professional ones.

The weather station compiled in this report has turned out to be very expensive and erring more towards the professional realm rather than the amateur home use case.

Consideration has to be taken into output power from each signal source as this will determine weather signal conditioning is required, and the input power requirements are vital in choosing the correct power/ battery source.

Additionally, the type of interface protocol that each sensor uses is paramount in choosing the correct PIC: if the PIC does not support for instance I2C, then a sensor using I2C protocol cannot be used.

5. Recommendations

For future iterations of this project, the following recommendations are made:

- Add a rainfall gauge
- Add a Barometer
- Connector type considerations – this should be considered early on in the process to ease the PIC search process.

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ESD 2 Assignment

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

55/100

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GRADING FORM: SMU GENERIC_GJ

CAMERON FITZE

54.50

RESEARCH-INFORMED LITERATURE

- | | | |
|---|---|------------|
|  | Reasonable literature review of available systems with a good comparison table of relevant information but a short section of the manufacturers specification would have improved it. 68% | 6.8 |
|---|---|------------|

KNOWLEDGE AND UNDERSTANDING

- | | | |
|---|--|------------|
|  | The schematic and PCB files submitted were for an earlier project not this one 30% | 7.5 |
|---|--|------------|

ANALYSIS

- | | | |
|---|---|-------------|
|  | Good selection of microcontroller. Good selection of components well described and selected via the tables.. Good case selection. unfathomable selection of connectors .62% | 21.7 |
|---|---|-------------|

PRACTICAL APPLICATION AND DEP.

- | | | |
|---|--|-----------|
|  | Costings were included, they have been included in a table with an image and the manufacturers part number along with the supplier's name and part number. Poor attempt at future enhancements.60% | 12 |
|---|--|-----------|

SKILLS FOR PROFESSIONAL PRAC.



The report is reasonably presented with a poor selection of references. 65%

6.5