

ESD_2_Report

by Theo Rose

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Electronic Systems Design 2 Report



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L6 – Electronic Systems Design
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Embedded Electronics Degree Apprenticeship

Abstract

This assignment will cover the research and design process of creating a portable weather station capable of taking measurements across a 14-day period. Initially a literature review on existing products will be detailed and the key aspects of the systems found will be reflected in the design procedure later.

The next stage of this assignment is to find different environmental sensors that will fit the assignment brief, sufficiently protected against weather conditions and be able to operate over the 14-day period. The required sensors for this assignment are listed below:

- Temperature & Humidity
- Wind Speed & Direction
- UV & Light Intensity
- GPS
- VOC & Air Particle Count

Each of these sensors will require a down selection process to determine the most appropriate sensing technology and then the most appropriate specifications to interface with the rest of the system.

After the selection of sensors has been completed the next part of this document will detail the system schematic, PCB, software and over block diagram design procedure to ensure that it can operate. This section will document the design process and give reasoning behind why certain design choices were made with justification.

The final section will cover billing of material costs and future improvements for the next version of the system. These improvements will be heavily influenced by the literature review but were not necessary to include in this iteration due to the requirements from the brief.

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Literature Review

Weather Station Image	HOBO Cellular Weather Station Kit Advanced	VuWeather BFS500 Compact Weather Station	Davis Vantage Pro2
			
Features	• Solar panel • Temperature and humidity • Wind speed and direction (cup and wind vane) • Rain gauge • Barometric Pressure • Solar radiation • 4G cellular connection	• Heating function • Powered by solar panel (not included) • Wind speed and direction (Ultrasonic) • Pressure (Silicon piezoresistor) • Temperature and humidity • Compass • Optional extras: GPS, Cellular, Wi-Fi, Bluetooth, LoRa	• Touchscreen console • UV and solar radiation • Soil moisture • Rain gauge • Temperature and humidity • Solar panel • Wind speed and direction • Radiation shielding • Wi-Fi connectivity
Benefits	• Professional station with optional extras and configurable inputs for external sensors • Good range of quality sensors for accurate readings • Solar panel powered	• Configured to support a wide range of connectivity option upgrades • Smaller form factor by utilising ultrasonic wind speed and direction sensor • Heating function included for accurate results • Solar panel is not included	• Touch screen console to view data • Cheapest option for £1,575 • Solar panel powered
Drawbacks	• Expensive - costs £5,152.96 • Larger form factor		• Only supports Wi-Fi connectivity with included console • Cheaper choice of sensors to reduce cost

Table 1 - Comparison Table [1] [2] [3]

Table 1 shows the comparison of different weather stations available online that will be used to determine beneficial features to include in the design for this assignment. These systems range from top-of-the-line high end sensors with optional expansion options to all-in-one system with very limited optional extras [1]. The key areas found from market research on weather stations are:

- **IP Rating** – The system must be able to withstand outdoor weather ranging from heavy rain to high temperatures will remaining functional for long periods of time. The cheaper kits often have little to no water and dust resistance and are therefore not applicable for outdoor use.
- **Reliability and accuracy of the sensors** – The ideal choice of sensors would be the highest specification with excellent accuracy and appropriate operational range for UK weather. However, this usually comes with the drawback of higher costs and therefore a balance of cost to performance needs to be considered during sensor down selection.
- **Connectivity options** - The support for multiple connectivity options differ from suppliers between hobby kits and professional systems. This can be seen when comparing the Davis vantage Pro 2 [3] with the other two systems as it only offers Wi-Fi connectivity and has little expansion options to add external sensor.

Selection of Microcontroller

The choice of microcontroller is heavily influenced by the choice of sensors being used in the system which will be used to determine what features are needed, how many pins are required, what clock frequency is appropriate to sample the sensors, the amount of temporary onboard memory needed before being transferred to the external storage and a suitable voltage to interface between the sensors. This also includes a USB interface to read the sampled data back at the end of the 14-day period, an LED tell to turn on every 10 seconds to indicate status, programming and debugger port and a start/stop button to initiate sampling.

Most of the sensors operate on a 3.3V I2C logic protocol and therefore will share a data bus and two pins on the PIC. However, one of the sensors operates on 5V I2C logic which will require a 5V to 3.3V bi-directional logic level shifter to interface with the other I2C devices on the same bus. The last sensor requires two analogue pins and communicates through voltage sensing and voltage pulses to send the data. It therefore makes sense to use a microcontroller that has an operating voltage of 3.3V so the I2C logic works with the sensors natively.

After working out the sensors data transfer requirements, in total the PIC will need 2 digital pins for I2C, 2 digital pins for USB data transfer, 3 digital pins for SPI interface with an external SD card, 2 digital pins for debugging and programming, 1 pin for USB 5V sensing, 1 analogue pin for wind direction, 1 analogue pin for wind speed, 1 pin for LED tell and 1 pin for start/stop button. PIC microcontrollers often use MSSP ports to help reduce size and maintain capability as they can interface with different protocols [4]. It is essential that each interface has its own dedicated pins/port and therefore a PIC with more pins is required.

As mentioned above, the PIC will need to be able to interface via USB and have debugging/programming pins and it is essential that the PIC can run both USB and I2C using the internal clock.

Sensor	Rep time (sec)	Bytes per reading	Total Bytes	Reading/min	Bytes/min
Temp	60	4	4	1	4
Humidity	60	4	4	1	4
Wind Speed	60	2	2	1	2
Direction	60	2	2	1	2
UV	60	2	2	1	2
Light Intensity	60	7	7	1	7
GPS	10080	82	82	0	0
VOC&APC	60	25	25	1	25
		Total bytes per min		1	210
		Total bytes per hour		60	12600.00
		Total bytes per day		24	302400
		Total bytes per 14 days		14	4233600

Table 2 - Calculations for storage requirements and bytes per sample

As the system is only going to be sampling the sensors every minute, clock speed isn't much of a concern in respect to storing and managing the data throughput of the sensors. Table 2 shows that only 210 bytes of data are needed to be transferred via SPI to the SD card every minute so that is the minimum amount of RAM required.

The minimum requirements, stated above, will all need to apply to the choice of microcontroller. For this system, the PIC microcontroller that fits these specifications is the PIC18F47J53. This PIC has 44 pins in total and can support all the I/O required, it has 2 MSSP ports that can be dedicated to SPI and I2C, also supports USB, debugging/programming through ICSP pins and has an operating voltage of 3.3V which is needed to interface with the 3.3V I2C logic of the sensors [4]. The PIC has 5.5V tolerable pins which can allow interfacing with 5V logic I2C but for this system a logic shift level IC will be used to protect the other sensors sharing the data bus [4]. The microcontroller has tuneable clock frequency depending on requirements and a built-in phase lock loop blocks to ensure that the microcontroller is compatible with a low-speed USB configuration [4]. By taking the 8MHz internal clock frequency in conjunction with the PLL to achieve 48MHz.

Selection of Case, Storage, Sensors, and Connectors

Case:



Figure 1 – Pelicase [5]

The selection of case will be two watertight cases from helicase, one will be for the sensors and PCB and the other will house the Anker power station.

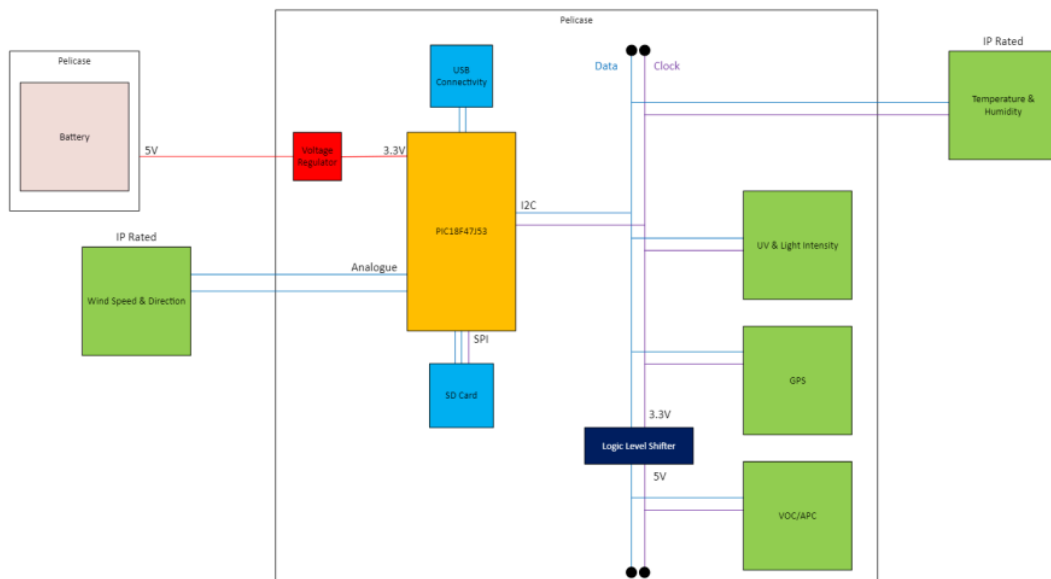


Figure 2 – System Block Diagram

Figure [2] shows how the system will be structured with the battery in a separate pelicase with IP rated power connectors transferring power to the main pelicase housing most of the sensors. A separate air channel will be passed through one side of the case to ensure the VOC/APC can sample the quality of the air. And a window for the UV and light intensity to sample data.

Storage:

It is important to ensure that all data acquired by these sensors are stored in a form of non-volatile memory so when the system isn't powered the data is still retained. For this system, an external SD card will be used to permanently store any data collected.



Figure 3 – SD Card [6]

Sensor	Rep time (sec)	Bytes per reading	Total Bytes	Reading/min	Bytes/min
Temp	60	4	4	1	4
Humidity	60	4	4	1	4
Wind Speed	60	2	2	1	2
Direction	60	2	2	1	2
UV	60	2	2	1	2
Light Intensity	60	7	7	1	7
GPS	10080	82	82	0	0
VOC&APC	60	25	25	1	25
Total bytes per min				1	210
Total bytes per hour				60	12600.00
Total bytes per day				24	302400
Total bytes per 14 days				14	4233600

Table 3 - Calculations for storage

The calculations to work out an appropriate amount of storage is shown above in Table 3. This involves using the sample time of 1 min multiplied by the number of bytes each sensor outputs to work out the total bytes per reading. This works out to approximately 210 bytes of data per reading which is then used to calculate the total amount of bytes for the 14-day period. The total amount of bytes, as seen in Table 3, is 4,233,600 which will be the minimum storage requirement for this system. Therefore, a suitable size of storage would be at least a 5MB SD card so a 1GB Mini SD card, seen in Figure [6], is chosen.

Sensors:

Temperature and Humidity:

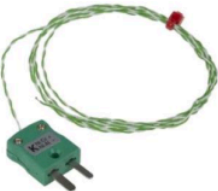
Component	Temperature	Temperature	Temperature & Humidity
Photo			
Type	Optical	Thermocouple	Resistive
Manufacturer	RS PRO	RS PRO	Measurement Specialists
Component Number	RS PRO V Output Signal Infrared Temperature	RS PRO Type K Thermocouple	HPP809A031:HTM2500LF
Supplier	RS	RS	RS
Supplier Number	161-8103	363-0250	893-7373
Operating Range	0 - 1000	-75 to 250	-125
Current Draw	30mA	N/A	1.2 mA
Supply Voltage	6-24V	N/A	5V
Output Voltage	0-10V	N/A	2.4-2.6V
Response Time	250ms	N/A	10 sec
IP Rating	IP65	N/A	N/A
Accuracy	+/- 1.5%	N/A	Temp +/- 1% Humidity +/- 2%
Interface	Analogue	Analogue	Analogue
Number of Pins	4	2	5
Total Price	203.47	9.73	119.08

Figure 4 – Temperature type down selection [7] [8] [9]

Component	Humidity	Humidity
Photo		
Type	Resistive	Capacitive
Manufacturer	RS PRO	IST INNOVATIVE SENSOR TECHNOLOGY
Component Number	RS PRO Humidity Sensor	MK33-W
Supplier	RS	RS
Supplier Number	246-5637	169-9923
Operating Range	0 to 90%	0 to 100 RH
Current Draw	0.26mW	N/A
Supply Voltage	AC 1V	12
Output Voltage	1V	N/A
Response Time	<20 sec	<6
IP Rating	N/A	N/A
Accuracy	± 3%RH	0.45 pF/%
Interface	Analogue	Analogue
Number of Pins	2	2
Total Price	2.81	38.9

Figure 5 – Humidity type [10] [11]

Component	Temperature & Humidity	Temperature & Humidity	Temperature & Humidity
Photo			
Type	Resistive	Resistive	Resistive
Manufacturer	Measurement Specialists	Amphenol Advanced Sensors	Gemini
Component Number	HPP809A031:HTM2 500LF	T9602-5-D-1	Tinytag TGP-4500
Supplier	RS	RS	RS
Supplier Number	893-7373	257-9568	509-6983
Operating Range	-40 to 85	-20 to 70	-25 to 85
Current Draw	1.2 mA	750uA	
Supply Voltage	5V	3.3-5V	3.6V
Output Voltage	2.4-2.6V	0-5V	5V
Response Time	10 sec	Temp <116, Humid <29	1 sec
IP Rating	N/A	IP67	IP68
Accuracy	Temp +/- 1%, Humidity +/- 2%	Temp +/- 0.5, Humid +/- 2	0.01°C
Interface	Analogue	Digital (I2C)	USB/Serial
Number of Pins	5	4	4
Quantity	1	1	1
Price Per Unit	119.08	43.04	232.52

Figure 6 – Sensor down selection [9] [12] [13]

The first sensor is a combination of temperature and humidity which will send all the data over the I2C protocol. The process of selecting this sensor was to first look at the different types of sensors and down select from there by choosing the most appropriate sensor depending on the operating voltage, IP rating and operating range.

Shown in Figure [6] is the three chosen sensors for down selection and because the sensor will need to have an IP rating and communicate of I2C the Amphenol Advanced Sensor was chosen [12]. This sensor provides a good IP rating suitable for UK weather and an appropriate operating voltage that will work with the PIC.

Windspeed and Direction:

Component	Wind speed	Wind speed	Wind speed
Photo			
Type	Cup	Ultrasonic	Hotwire thermo-anemometer
Manufacturer	MeteoWind	Gill	Sauermann
Component Number	MeteoWind Compact	WindSonic 1	VT110-VT115
Supplier	Instrument Choice	Richard Paul Russel LTD	RS
Supplier Number	IC-MeteoWind	WS-GIL-WS1-1405-PK-021	241-0455
Operating Range	0 to 85 m/s	0 to 134mph 0 to 359	0.15 to 30 m/s
Current Draw	50uA	5.5mA @12V	N/A
Supply Voltage	3.2-15V	5 to 30V	4 x AAA 1.5V Bat
Output Voltage	0-2.5V	0-5V	N/A
Response Time		0.25 sec	N/A
IP Rating	IP65W	IP65	IP54
Accuracy	0.1 m/s	+/- 2% +/- 4%	+/- 0.2 m/s
Interface	Analog	RS232/422/485/Analogue	N/A
Number of Pins	2	9	N/A
Total Price	318.55	1,069.20	£674.53

Figure 7 – Windspeed selection [14] [15] [16]

Component	Wind direction	Wind direction
Photo		
Type	Windvane	Ultrasonic
Manufacturer	MeteoWind	Gill
Component Number	MeteoWind Compact	WindSonic 1
Supplier	Instrument Choice	Richard Paul Russel LTD
Supplier Number	IC-MeteoWind	WS-GIL-WS1-1405-PK-021
Operating Range	0 to 85 m/s	0 to 134mph 0 to 359
Current Draw	50uA	5.5mA @12V
Supply Voltage	3.2-15V	5 to 30V
Output Voltage	0-2.5V	0-5V
Response Time		0.25 sec
IP Rating	IP65W	IP65
Accuracy	0.1 m/s	+/- 2% +/- 4%
Interface	Analog	RS232/422/485/Analogue
Number of Pins	2	9
Total Price	318.55	1,069.20

Figure 8 – Wind direction selection [14] [15]

Component	Wind Speed and Direction	Wind Speed and Direction	Wind Speed and Direction	Wind speed and direction
Photo				
Type	Cup and wind vane	Cup and wind vane	Cup and wind vane	Cup and wind vane
Manufacturer	Onset	BMS Parts	Omni Instruments	MeteoWind
Component Number	HOBOnet Wind Speed and Direction Sensor	Wind Speed & Direction Sensor 4-20mA SEN-15901	Meteo Anemometer for Wind Speed and Direction (meteoprobe)	MeteoWind Compact
Supplier	RSHydro	BMS Parts	Omni Instruments	Instrument Choice
Supplier Number	RXWONWCFON868	AV-WSD-20	93.0406	IC-MeteoWind
Operating Range	0-170 mpg 0 to 355 degrees	0-50 m/s 0 to 360 degrees	2.5 to 210km/h 0 - 360	0 to 85 m/s
Current Draw	>12.6mW		N/A	50uA
Supply Voltage	1.2-1.5V	0-10V	1V	3.2-15V
Output Voltage	N/A	0-10V or 4-20mA	0-2V	0-2.5V
Response Time	1 min	N/A	N/A	
IP Rating	IP67	N/A	N/A	IP65W
Accuracy	0.5m/sec - 1.4 degrees	5%	0.3 m/s and 2 degrees	0.1 m/s
Interface	Wireless	Analog	Analog	Analog
Number of Pins	N/A	4	4	2
Quantity	1	1	1	1
Price Per Unit	£631.62	£748	1,137.26	318.55

Figure 9 – Down selection [17] [18] [19] [14]

For wind speed and direction, there are three main types that can be used which can be seen in figure [9]. From this the most appropriate sensor for simplicity, cost, interfacing, IP rating and accuracy is the MeteoWind Compact seen in Figure [9].

UV and Light Intensity:

Component	Lux Meter	Lux Meter	Lux Meter
Photo			
Type	Photodiode	Photoresistors	Phototransistors
Manufacturer	DFROBOT	OKDO	Sharp
Component Number	Gravity: Analog Ambient Light Sensor TEMT6000	TS2134-A	PT480FE0000F
Supplier	Pi Hut	RS	RS
Supplier Number	SEN0043	257-6759	315-860
Operating Range	1-1000 Lux	N/A	Relative sensitivity
Current Draw	20mA	N/A	3mA
Supply Voltage	5V	3.3-5V	6V
Output Voltage	5V	Analogue	Analogue
Response Time	N/A	N/A	3uS
IP Rating	N/A	N/A	N/A
Accuracy	N/A	N/A	N/A
Interface	Analogue	Analogue	Analogue
Number of Pins	3	1	2
Total Price	5.7	5.57	0.4

Figure 10 – Light type selection [20] [21] [22]

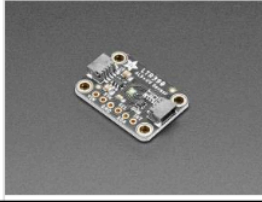
Component	UV	UV	UV	UV & Light
Photo				
Type	Photodiode	Photodiode	Photodiode	Photodiode
Manufacturer	Seed	Adafruit	DFROBOT	DFROBOT
Component Number	101020043	LTR390 UV Light Sensor - STEMMA QT / Qwiic	Gravity: Analog UV Sensor V2	Gravity: Multifunctional Environmental Sensor
Supplier	Farnell	Pi Hut	Pi Hut	Pi Hut
Supplier Number	4007676	ADA4831	SEN0162	SEN0501
Operating Range			UV/A	UV-A/B
Current Draw	0.31mA	100mA	0.1mA	45mA
Supply Voltage	5V	5V	5V	3.3-5V
Output Voltage	<5V	3.3V	0-1V	3.3V
Response Time				<500ms
IP Rating	N/A	N/A	N/A	N/A
Accuracy		25%	+/- 1 UV index	
Interface	analogue	I2C	Analog	I2C,UART
Number of Pins	4	5	3	4
Total Price	£11.05	£4.80	£5.70	£28.90

Figure 11 – UV selection [23] [24] [25] [26]

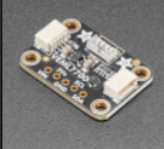
Component	Lux Meter	Lux Meter	UV & Light	Lux Meter
Photo				
Type	Photodiodes	Photodiodes	Photodiode	Photodiode
Manufacturer	Adafruit	DFROBOT	DFROBOT	DFROBOT
Component Number	VEML7700	Ambient Light Sensor(0-200klx)	Gravity: Multifunctional Environmental Sensor	Gravity: Analog Ambient Light Sensor TGMT6000
Supplier	Pi Hut	Pi Hut	Pi Hut	Pi Hut
Supplier Number	ADA4162	SEN0390	SEN0501	SEN0043
Operating Range	0 - 120 klux	0-200 klux	UV-A/B	1-1000 Lux
Current Draw	100mA	0.7mA	45mA	20mA
Supply Voltage	5V	5V	3.3-5V	5V
Output Voltage	3.3V	3.3V	3.3V	5V
Response Time	<800 ms	<800ms	<500ms	
IP Rating	N/A	N/A	N/A	N/A
Accuracy		0.054lx		
Interface	I2C	I2C	I2C,UART	Analogue
Number of Pins	5	5	4	3
Total Price	£4.80	£9.00	£28.90	£5.70

Figure 12 – Combination down selection [27] [28] [26] [20]

Types of UV and Light Intensity sensors are seen in Figure [12] and the down selection was worked out by the operating voltage, interfacing and combination of both. For this sensor the DFROBOT gravity environmental sensor was chosen as it fits all the criteria and can communicate via the I2C bus. This sensor does not need to be IP rated as it will be in the enclosure with a built-in window.

GPS:

Component	GPS	GPS	GPS	GPS
Photo				
Type	Sat	Sat	Sat	Sat
Manufacturer	UBLOX	UBLOX	UBLOX	ADAFRUIT
Component Number	Ublox NEO-6M GPS UART Module Breakout with Antenna	SAM-M8Q	uBLOX MAX-M8C	Adafruit Ultimate GPS Breakout with GLONASS + GPS - PA1616D - 99 channel w/10 Hz updates
Supplier	Pi Supply	Sparkfun	Pi Hut	Pi Hut
Supplier Number	PIS-1219	GPS-15210	102630	ADA5440
Operating Range		GPS/GLONASS	S, Galileo, GLONASS, BeiD	GPS, GLOSNAASS
Current Draw		67mA	67mA	30mA
Supply Voltage	3.3-5V	3.3V	3.3v	5V
Output Voltage	3.3-5V	I2C	I2C	3.3V
Response Time		100ms	100ms	
IP Rating	N/A	N/A	N/A	N/A
Accuracy		2.5m		<3m
Interface	UART TTL	I2C/UART	I2C	UART
Number of Pins	5	8	6	9
Total Price	8.33	34.12	24	29.8

Figure 13 – GPS selection [29] [30] [31] [32]

For the GPS sensor, the down selection was determined by the operating voltage included extras and the size of the device as seen in figure [13]. The choice for this sensor was the UBLOX MAX-M8C as it has a built in GPS antenna on the PCB and can communicate over I2C at the correct logic level [31].

VOC/APC:

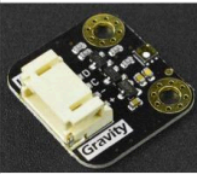
Component	VOC	VOC
Photo		
Type	MOS/MOX	EGS
Manufacturer	DFROBOT	SGX Sensors
Component Number	Gravity: SGP40 Air Quality Sensor	PS4-VOC-200
Supplier	Pi Hut	RS
Supplier Number	SEN0394	254-1587
Operating Range	0-500 index	0-200ppm
Current Draw	2.6mA	100nA
Supply Voltage	5V	N/A
Output Voltage	I2C	Analogue
Response Time	2 Sec	<30 sec
IP Rating	N/A	N/A
Accuracy		15nA / ppm
Interface	I2C	Analogue
Number of Pins	4	3
Total Price	13.3	55.36

Figure 14 – VOC selection [33] [34]

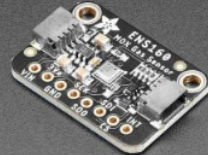
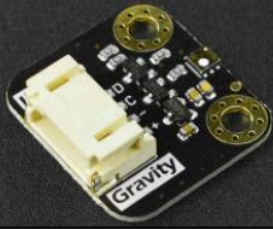
Component	VOC	VOC/APC	VOC	VOC
Photo				
Type	MOS/MOX	MOS/MOX, Optical	MOS/MOX	MOS/MOX
Manufacturer	Sparkfun	Sensirion	ADAFRUIT	DFROBOT
Component Number	Sensirion SGP40	SEN55-SDN-T	ENS160 MOX Gas Sensor	Gravity: SGP40 Air Quality Sensor
Supplier	Pi Hut	RS	Pi Hut	Pi Hut
Supplier Number	SEN-18345	240-9021	ADA5606	SEN0394
Operating Range	1 to 500 index	1 to 500 index, 0.3 to 10 um	0-65k ppm	0-500 index
Current Draw	2.6mA	100mA	79mA	2.6mA
Supply Voltage	3.3V	5V	5V	5V
Output Voltage	I2C	5V	I2C	I2C
Response Time	1 Sec	<60s	1 sec	2 Sec
IP Rating	N/A	N/A	N/A	N/A
Accuracy		25ug, +/-5%	<12%	
Interface	I2C	I2C	I2C/SPI	I2C
Number of Pins	4	6	4	4
Total Price	£17.00	£23.22	£21.90	£13.30

Figure 15 - VOC selection [35] [36] [37] [33]

Component	APC	VOC/APC	APC	APC
Photo				
Type	Optical	MOS/MOX, Optical	Optical	Optical
Manufacturer	Tera	Sensirion	DFROBOT	Piera Systems
Component Number	TERA Sensor Next-PM	SEN55-SDN-T	Gravity: Laser PM2.5 Air Quality Sensor	IPS-5100-1
Supplier	RS	RS	RS	Farnell
Supplier Number	195-3770	240-9021	SEN0177	4015787
Operating Range	0.3 - 10 um	1 to 500 index, 0.3 to 10 um	0.1 - 10 um	0.1 - 10 um
Current Draw	300mA	100mA	120mA	65mA
Supply Voltage	5V	5V	5V	5V
Output Voltage	3.3V	5V	3.3V	3.3V
Response Time	1 sec	<60s	<10 sec	<1 Sec
IP Rating	N/A	N/A	N/A	N/A
Accuracy	95%	25ug, +/-5%	50%@0.3um, 98%@≥0.5 um	+/- 10%
Interface	UART	I2C	RS232	I2C
Number of Pins	4	6	9	5
Total Price	£81.89	£23.22	£45.00	£69.42

Figure 16 – APC selection [38] [36] [39] [40]

The VOC/APC sensor selection shown in was mainly determined by which offered the best operating range with a decent accuracy. The Sensirion MOS/MOX and optical sensor fit the requirement brief well as it offered a combination of both sensors at a suitable voltage for the system [36].

Connectors:

Only the wind direction and speed and the temperature sensors require IP rating as they will be exposed to the outside weather conditions. The other sensors will remain in the housing to ensure they remain protected from the outside environment. The two sensors that will require external mounting will be fitted with a complementary pair of binder connectors with a rating of IP67 to ensure sufficient protection against water and dust.



Figure 17 - Binder Connectors [41]

The connectors chosen for this system will be from the binder 620 series but will have different number of contacts depending on the sensor being used. They will be mounted on the bottom of the case and will ensure a watertight passthrough to the PCB mounted inside the case.

Battery:



Figure 18 – Battery [42]

Total Current	234mA
Min for 1 day	5616mA
Min for 14 days	78624mA

Table 4 - Current consumption calculations

A suitable battery for this system needs to output a 5V source voltage and needs to be able to supply a minimum current determined by the sensors and microcontroller requirements. Using the datasheets provided by the sensors the max current consumption can be calculated to work out an appropriate battery capacity. Table 4 shows the max current calculations for 14 days and therefore the battery will need at least 78624mA capacity and able to output at least 0.5 amps to operate all the sensors and components on the PCB.

The chosen battery to fulfil these requirements is the Anker SOLIX 521 Portable Power Station with a total capacity of 1056 Wh which converts to 211200 mAh when drawing 5V [42]. Which will provide more than enough capacity to run the weather station for 14 days.

Circuit Schematic and PCB Design

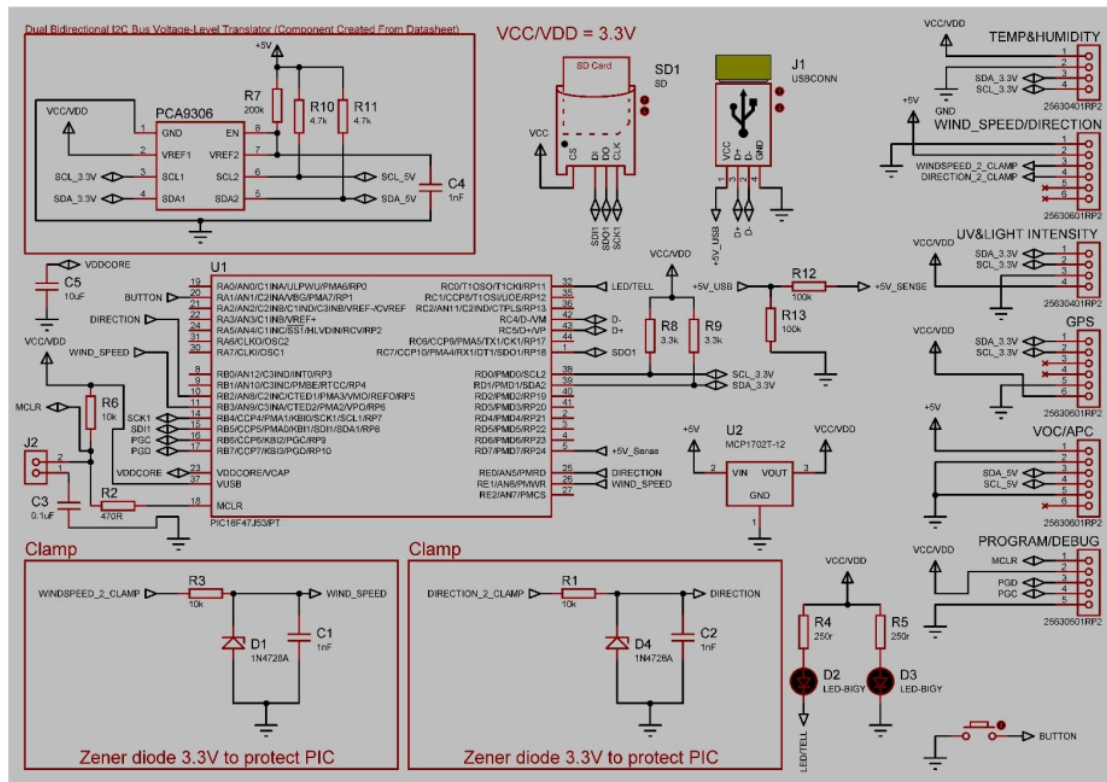


Figure 19 – Proteus System Schematic [43]

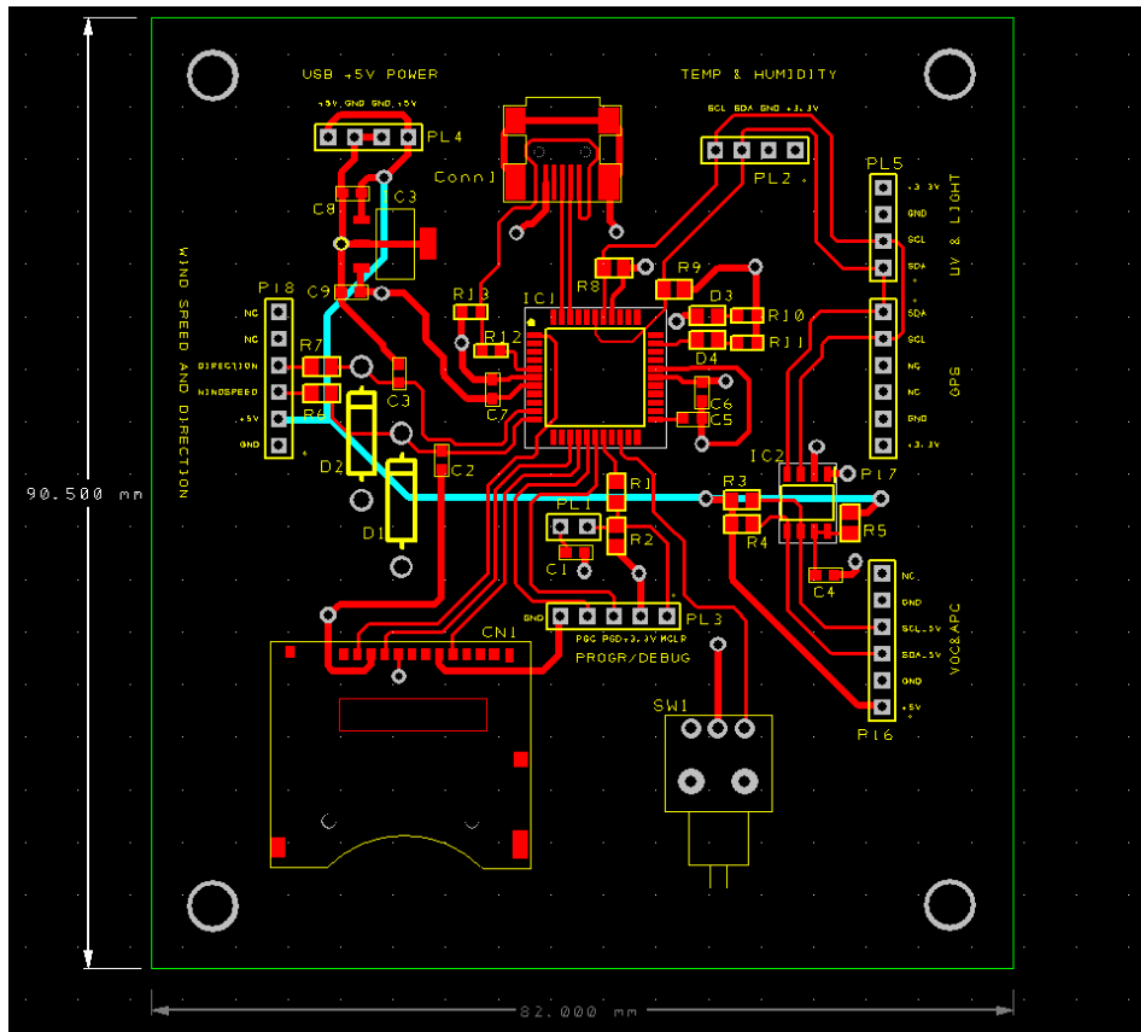


Figure 21 - Easy-PC PCB Design [44]

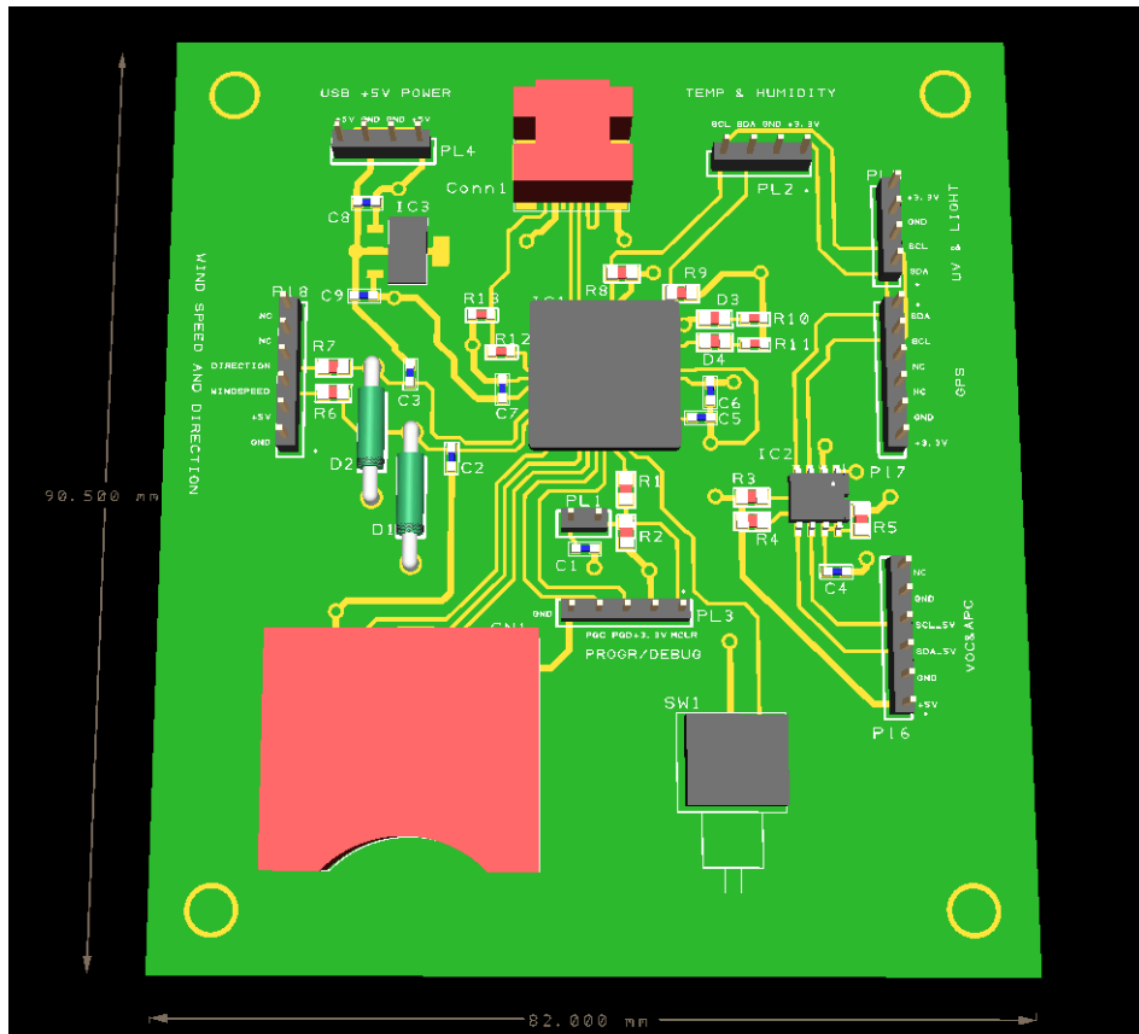


Figure 22 - 3D View of PCB [44]

Figure [22] shows the easy-pc schematic for the weather station system with each section outlined to separate each interface with the microcontroller. This system primarily uses the I2C digital protocol to communicate between the selected sensors except for the wind speed and direction that use an analogue input.

I2C:

I2C is a common protocol used for low data rate transfer between devices at an optimal distance of less than 1m [45]. It is important to keep the distance between the microcontroller and sensor as short as possible to avoid signal degradation.

As most of the sensors have an operating voltage of 3.3V they can easily and safely interact with the I2C pins on the microcontroller. However, the VOC/APC sensor has an operating voltage of 5V and therefore operates at a higher logic level. As the sensors share the same bus, it is not applicable to use varying I2C logic levels on the same bus without protection because it will damage the sensors. To resolve this issue the VOC/APC sensor will be connected to a bi-directional logic level shifter/translator to allow direct translation from 5V to 3.3V to enable communication on the same bus as the other sensors. The integrated circuit used to achieve this is the PCA9306 from Texas instruments [46]. This also requires the data bus to have two sets of pull up resistors on both data lines as it needs one set for the 5V logic level and one set for the 3.3V logic level [46].

Voltage Regulator:

The voltage regulator chosen for this system will be the LM3940 low drop out regulator which will take 5V input voltage and convert it to 3.3V for operating the PIC and the external sensors [47]. This can output up to 1 amp of current which will be enough to supply the components.

SPI:

The external SD cards storage will interface with the PIC through 3.3V SPI bus which requires 3 pins to send data. These pins are SCK which is the output clock from the PIC to synchronise the timings, the SDI pin which will receive data from the SD card and the SDO pin which will output data [4].

USB:

For this system a USB interface is being used to extract data from the system shown in Figure [20]. The chosen power configuration from the datasheet is "Self-Power only" which allows the USB host to provide power over the VUSB pin when the USB host device is ready to start communication. By connecting the VBUS bus pin into a sensing pin it can be used to initiate USB communication to comply with the USB standards [4].

The built-in USB transceiver is only capable of low-speed data rates over USB when using the internal clock and PLL to achieve the minimum 48MHz clock speed for USB [4].

Power Connectivity:

The first stage of the power system is to convert the input 5V from the power supply to 3.3V to power the PIC this process is described above. From the regulator, power to the PIC with capacitors attached to both VDD pins and then tied to ground is the advised setup according to the advised specifications [4].

Analogue Inputs:

For the 2 analogue inputs from the wind speed and direction sensors a 3.3V clamp, seen in figure [20], is applied on both the inputs to ensure the PIC isn't damaged by any spurious voltages.

Debugger/Programming pins:

Figure [20] shows the configuration of the debugging and programming pins following the ISCP specification [4]. This is to ensure that the PGC and PGD pins can be safely used without and risk of damage.

Figure [21] shows the PCB design of the schematic described above which includes 6 separate layers. Utilising the power planes ensures that there are less tracks to route on the bottom and top copper ultimately freeing up the top copper to route most of the data traces without as much interference.

The four holes on the corner of the PCB are mounting holes to allow the PCB to securely placed within the case it uses the standard M4 screw to do this.

The built-in design rule checks within the software allows the spacing, size of tracks and correct connections to be checked prior to the manufacture of the PCB.

Software Flowchart

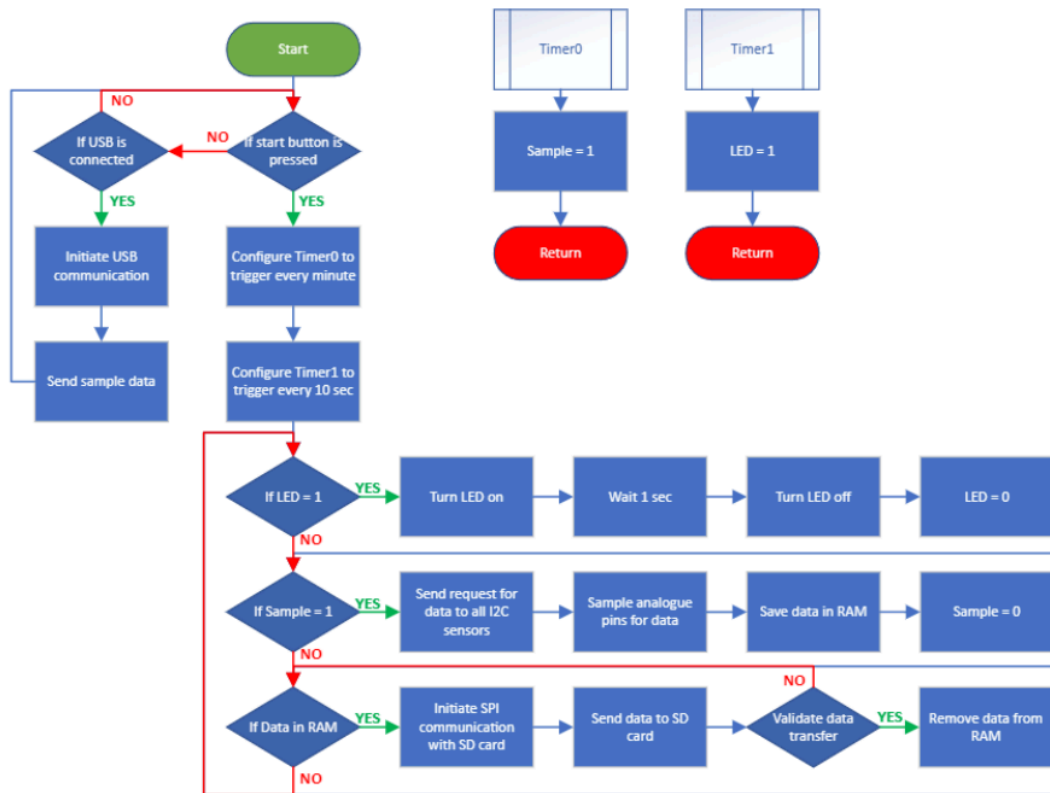


Figure 23 - Software Flowchart

The software flowchart shown in Figure [23] shows the process of how the system will operate. It will first configure two of the internal timers to trigger interrupts every 10 and 60 seconds for flashing the LED tell every 10 seconds and to sample the sensors every 60 seconds. The system will also have a start button to initiate the measurements after setup but after it is pressed it will continue to record measurements until it is power cycled. The system after being power cycled will then enter status check on the USB voltage pin for communication.

The data will contain a time of the sample, an identifier to match the data to the sensor and following that will be the values recorded by the sensor. The output of the data will be in the form of a .CSV which means each of the values will be separated by commas and can be read by applications such as excel for data analysis and representation.

Build Costings

Part	Component	Price per unit	Amount	Total Price
Temp & Humidity	T9602-5-D-1	43.04	1	£43.04
Wind speed & direction	MeteoWind Compact	318.55	1	£318.55
UV and light	Gravity: Multifunctional Environmental Sensor	28.9	1	£28.90
GPS	uBLOX MAX-M8C	24	1	£24.00
VOC/APC	SEN55-SDN-T	23.22	1	£23.22
Connector	binder male Connector, 4 Contacts, 620 series	8.35	1	£8.35
Connector	binder female Connector, 4 Contacts, 620 Series	9.59	1	£9.59
Connector	binder male Connector, 3 Contacts, 620 series	4.88	1	£4.88
Connector	binder female Connector, 3 Contacts, 620 Series	5.71	1	£5.71
USB C to 4 pin	Short USB C to 4 Pin Bare Wire	6.99	1	£6.99
Power Connector	binder male Connector, 3 Contacts, 620 series	4.88	1	£4.88
Power Connector	binder female Connector, 3 Contacts, 620 Series	5.71	1	£5.71
PCB		43.31	1	£43.31
Battery Pelicase	iM2750 Storm Case	352.2	1	£352.20
Sensor Pelicase	iM2450 Storm Case	205.06	1	£205.06
Mini SD card	1GB MiniSD Card	3.79	1	£3.79
Battery	Anker SOLIX C1000 Portable Power Station	800	1	£800.00
MCU	PIC18F47J53	5.45	1	£5.45
Voltage Regulator	LM3940	1.39	1	£1.39
Logic Level Shifter	PCA9306	0.79	1	£0.79
SMD Capacitor	SMD Capacitor	0.59	9	£5.31
Diode	3.3V diode	0.11	2	£0.22
SMD LED	Green LED	0.26	2	£0.52
Pin Header	6 Pin header	0.73	3	£2.19
Pin Header	5 Pin header	0.73	1	£0.73
Pin Header	4 Pin header	0.29	3	£0.87
Pin Header	2 Pin header	0.16	1	£0.16
USB C Connector	USB C SMD connector	0.86	1	£0.86
SMD Resistor	SMD Resistor	0.24	13	£3.12
SD Connector	SD MINI SMD connector	2.86	1	£2.86
Button	Push button	3.61	1	£3.61
		Total	57	£1,916.26

Table 5 - Build costings

Table [5] shows the total cost of building the weather system which includes all the sensors, and the additional extras required to keep the system IP rated and powered. The price of the PCB was calculated by using the JLCPCB website for manufacturing and shipping costs [48].

Suggested Improvements

Using the evidence gathered in the literature review here are the suggested improvements for the next version of the device:

- Adding an external oscillator to allow the PIC to make use of the high-speed USB data rates.
- Adding optional extras to allow alternative connectivity options such as cellular.
 - This will avoid the need to be directly connected to the device to receive data.
- Adding a heating element to ensure sensors operate at the most efficient temperature.
 - It is commonly seen from the literature review that these systems include heating elements keep components at a suitable temperature to retain accuracy in the results.

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ESD_2_Report

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

73/100

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GRADING FORM: SMU GENERIC_GJ

THEO ROSE

73.00

RESEARCH-INFORMED LITERATURE



Reasonable literature review of a number of available systems with a good comparison table of

6.5

relevant information but more detail would have improved it. 65%

KNOWLEDGE AND UNDERSTANDING

 Good overall schematic design but a things to be kept in mind. When designing a complex board it is beneficial, from a understanding point of view, to limit the number of lines travelling around and instead use net names which you have done. The 5V_sense you have used to indicate that the sub is connected is limited to 2.5 volts to the chip due to the resistor values, this did not need to be limited as the PIC digital inputs are 5.5V tolerant. The caps on the clamp should be 100nF. Your PCB is good only showing 1 error when checked. 72%

18

ANALYSIS

 Good selection of microcontroller. Good selection of components very well described and selected via the tables.. Good case selection. Good selection of connectors .78%

27.3

PRACTICAL APPLICATION AND DEP.

 Costings were included in a table without an image but with the supplier's name and part number. Limited attempt at future enhancements. 68%

13.6

SKILLS FOR PROFESSIONAL PRAC.



The report is well presented with a very good selection of references. 76%

7.6