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14 DAY WEATHER AND AIR QUALITY MEASUREMENT AND LOGGING SYSTEM

ACDA6002: ELECTRONICS SYSTEM DESIGN

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Background

This report covers the development of a weather station for logging data over a 14-day period.

Definition

Weather stations, utilising instrumentation to measure meteorological data, allow conditions at a specified sampling interval to be documented over a defined period [1].

Literature Review

In Table 1 a number of existing weather station solutions are evaluated. Whilst each of the systems discussed meet some of the design criteria of the proposal, no system completely satisfies all of the design criteria – leading to the development of the system within this report.

Manufacturer	Ecowitt	Bresser	Davis Instruments	Castella
Model No.	WS2910	7003800	Vantage 2 Pro	Guardian 2
Vendor	Amazon UK	Weather Station Products UK	Weather Station Products UK	Castella UK
Vendor Link	[2]	[3]	[4]	[5]
Product Image	Figure 1	Figure 2	Figure 3	Figure 4
Product Cost (£)	120.81	358.99	991.26	POC
Connectivity	WiFi (868mHz)	WiFi (868mHz)	WiFi	WiFi/GSM
Power Supply	5VDC PSU, AA/AAA (battery backup)	230VAC, AA/AAA (battery backup)	230VAC, Solar (Sensors)	240VAC, Battery, or Solar
Extra Features	Indoor Sensor Suite	Mobile App	Cloud/Mobile App 300m range	SMS/WiFi (Cloud logging)
Temperature (Indoor)	Y	Y	Y	
Temperature (Outdoor)	Y	Y	Y	
Humidity (Indoor)	Y	Y	Y	
Humidity (Outdoor)	Y	Y	Y	
Atmospheric Pressure	Y	Y	Y	
Ultraviolet Light (UVA/UVB)	Y	Y	Y	
Wind Speed	Y	Y	Y	Y
Wind Direction	Y	Y	Y	Y
Rainfall	Y	Y	Y	
Dew Point		Y	Y	
Leaf Wetness			Y	
Water Temperature			Y	
Light Intensity		Y	Y	
Soil Moisture			Y	
Soil Temperature			Y	
Airborne Particle Count (PM2.5/10)			Y	Y
Volatile Organic Compounds				Y
Noise/Vibration				Y

Table 1: Existing Systems Literature Review



Figure 1: Ecowitt WS2910 Outdoor Weather Station [2]

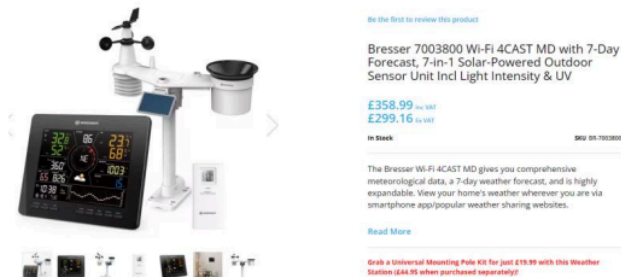


Figure 2: Bresser 7003800 Outdoor Weather Station [3]



Figure 3: Davis Vantage Pro2 Wireless Outdoor Weather Station [4]



Figure 4: Castella Guardian 2 Boundary Monitor [5]

Hardware Specification

Sensors

GPS

Global Positioning System (GPS) is a satellite-based navigation system utilising a constellation of 24 satellites to provide position, time, and heading; in civilian applications, GPS is accurate to 10 metres [6].

Table 2 shows the GPS modules considered. Each of these modules have an internal antenna, some holding the option to use an external antenna to improve reception.

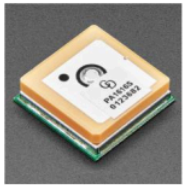
Part No.	Form Factor	Manufacturer	Interface	Power	IP	Vendor	Unit(£)
ADA4415 (Board) PA1010D (GPS IC) #1		Adafruit (Board) CDTop Tech (GPS IC)	I2C or UART	3-5V	N/A	thepihut.com Adafruit Mini GPS PA1010D – UART and I2C – STEMMA QT The Pi Hut	29.40
PIM525 (Board) PA1010D (GPS IC) #2		Pimoroni (Board) CDTop Tech (GPS IC)	I2C	3-5V	N/A	thepihut.com PA1010D GPS Breakout The Pi Hut	29.70
ADA790 (Board) PA1616S (GPS IC) #3		Adafruit (Board) CDTop Tech (GPS IC)	I2C or UART	3.3V	N/A	Pimoroni.com Ultimate GPS Module - 66 channel w/10 Hz updates - PA1616S - MTK3339 Chipset	25.80
L76-M33 (Module) #4		Quectel (Module)	UART	2.8- 4.3V	N/A	uk.rs-online.com Quectel L76-M33 GPS Receiver RS	8.71

Table 2: GPS Module Evaluation

From Table 2, GPS module #1 has been selected. The reasoning being that it utilises I2C, which is a multipoint-to-multipoint bus topology as opposed to UART which is point-to-point, which would otherwise reduce the number of hardware UART peripherals [7].

Temperature

Temperature is the measurement of hotness or coldness of an object, usually measure in Celsius ($^{\circ}\text{C}$) or Fahrenheit ($^{\circ}\text{F}$) [8].

Sensor Type	Advantages	Disadvantages
Thermocouples	Wide Temperature measurement range [9]	Slowest response time Low accuracy (1-2°C) [9]
Thermistors (NTC/PTC)	Low cost Relatively accurate [10] [11]	Slow response time [10] [11]
Pyrometer	Contactless (Infra-red) [12]	Can only measure solid objects
Resistance Temperature Detector (RTD)	Highly accurate (0.2°C) [13]	Highly expensive [13]
Semiconductor	Accurate (0.5°C) Low power [13] [14]	Somewhat expensive compared to passives [13] [14]

Table 3: Temperature Sensor Types

In Table 4, the Semiconductor type of temperature sensor was considered, primarily due to the highly accurate measurement this type of sensor can offer when compared to the other types discussed above.

Part No.	Form Factor	Manufacturer	Interface	Power	IP	Vendor	Unit(£)
HPP809A033 #1		TE Connectivity	Analog	4.75-5.25 VDC	No	uk-farnell.com HPP809A033. Temperature/H umidity Sensor Farnell UK	110.49
SEN0385 (Module) SHT31 (IC) #2		DFROBOT (Module) Sensirion (IC)	I2C	2.4-5.5 VDC	65	digikey.com SEN0385 DFRobot Sensors, Transducers DigiKey	18.51
410-347 (Module) HDC1080 (IC) #3		Digilent (Module) Texas Instruments (IC)	I2C	3.3-5VDC	No	uk.rs- online.com Digilent Pmod HYGRO RS	14.96
SHT30-DIS- B2.5kS #4		Sensirion	I2C	2.2-5.5VDC	No	uk.rs- online.com SHT30-DIS- B2.5kS I2C RS	1.37

Table 4: Temperature Sensor Evaluation

From Table 4, the sensor #2 has been selected as it is the only IP65 waterproof option and ability to operate from a 2.8V, 3.3V, or 5V supply.

Humidity

Humidity can be considered as the water held in air as a vapour or gas [15]. Table 5 shows the types of Humidity sensor available.

Sensor Type	Advantages	Disadvantages
Thermal Hygrometer (Capacitive/Thermal)	Simple and robust [17].	Doesn't provide a human reference to humidity [16]
Psychrometer (Wet/Dry Bulb)	Gives humidity accounting for human skin [16].	Large, and requires 2 thermometers[16].

Table 5: Humidity Sensor Types

In Table 6, the Thermal type of Hygrometer sensor has been selected as the chosen sensor type, due to the greater size of a Psychrometer sensor.

Part No.	Form Factor	Manufacturer	Interface	Power	IP	Vendor	Unit(£)
HPP809A033 #1		TE Connectivity	Analog	4.75-5.25 VDC	No	uk-farnell.com HPP809A033, Temperature/Humidity Sensor Farnell UK	110.49
SEN0385 (Module) SHT31 (IC) #2		DFROBOT (Module) Sensirion (IC)	I2C	2.4-5.5 VDC	65	digikey.com SEN0385 DFRobot Sensors, Transducers DigiKey	18.51
410-347 (Module) HDC1080 (IC) #3		Digilent (Module) Texas Instruments (IC)	I2C	3.3-5VDC	No	rs-online.co.uk Digilent Pmod HYGRO RS	14.96
SHT30-DIS-B2.5kS #4		Sensirion	I2C	2.2-5.5VDC	No	rs-online.co.uk SHT30-DIS-B2.5kS I2C RS	1.37

Table 6: Humidity Sensor Evaluation

From Table 6, sensor #2 has been selected as it is IP65, so is suitable for outdoor use, and uses I2C, which makes it able to share a bus with other sensors [17].

Wind Speed

Wind speed is typically measured in Knots (Kts) and increases with elevation [18]. Wind speed may be measured using an Anemometer or estimated using a Windsack.

Sensor Type	Advantages	Disadvantages
Ultrasonic	Solid State device, robust as no moving parts [20].	Expensive when compared to cup anemometer
Vane/Cup	Simple and accurate.	Has moving parts so is more difficult to waterproof.
Acoustic Resonance	Solid State device, robust as no moving parts [20].	Expensive when compared to cup anemometer
Pitot Tube	Highly accurate and robust.	Expensive, requires high wind speeds to operate [19].
Windsack	Inexpensive and robust.	For estimation/Indication only up to 15Kts [20]. Cannot interface with a microcontroller.

Table 7: Wind Speed Sensor Types

The sensor types considered in Table 8 are of the Ultrasonic/Acoustic and vane type.

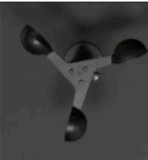
Part No.	Form Factor	Manufacturer	Interface	Power	IP	Vendor	Unit(£)
SEN0483 #1		DFROBOT	RS485 (Modbus)	7-24V	64	Digikey.co.uk SEN0483 DFRobot Sensors, Transducers DigiKey	40.33
AV-WSD #2		N/K	Analog (Pulsed)	N/K	65	BMSparts.co.uk Wind Speed and Direction Sensor - AV-WSD - BMS Parts	1368
ZQW-600 #3		ZHIQIONG	RS485 (Modbus)	N/K	N/K	Aliexpress.com RS485 Ultrasonic Wind Speed and Direction sensor AliExpress	64.19
SEN0170 #4		DFROBOT	Analog (0-5V)	12-24V	64	Thepihut.com Anemometer Kit (0-5V) The Pi Hut	46.10

Table 8: Wind Speed Sensor Evaluation

From Table 8, sensor #1 has been selected due its IP64 rating, wide operating voltage range (7-24V), and use of RS485. The RS485 interface may be derived from UART through an RS485 driver; RS485 also ensures signal reliability over distance as it utilises differential signalling [11].

Wind Direction

Wind directions is measured to true (non-magnetic) north and indicates the direction the wind is blowing from (not toward) [21].

Sensor Type	Advantages	Disadvantages
Wind Vane	Mechanical device, very simple hardware.	Susceptible to damage at high wind speeds if left exposed.
Ultrasonic	Solid State device, robust as no moving parts [20].	Expensive and complex when compared to a wind vane.
Acoustic Resonance	Similar operating principle to Ultrasonic Anemometer.	Expensive and complex when compared to a wind vane.
Windsock	Inexpensive and robust.	For estimation/Indication only [20]. Cannot interface with a microcontroller.

Table 9: Wind Direction Sensor Types

In Table 10, both Wind Vane and Ultrasonic Anemometers have been considered.

Part No.	Form Factor	Manufacturer	Interface	Power	IP	Vendor	Unit (£)
SEN0482 #1		DFROBOT	RS485 (Modbus)	7-24V	64	Digikey.co.uk SEN0482 DFRobot Sensors, Transducers DigiKey	34.89
AV-WSD #2		N/K	Analog (ADC)	N/K	65	BMSparts.co.uk Wind Speed and Direction Sensor - AV-WSD - BMS Parts	1368
ZQW-600 #3		ZHIQIONG	RS485 (Modbus)	N/K	N/K	Aliexpress.com RS485 Ultrasonic Wind Speed and Direction sensor AliExpress	64.19
101991044 #4		Seeed Technology	RS485 (Modbus)	12-24V	66	Digikey.co.uk 101991044 Seeed Technology Co., Ltd Sensors, Transducers DigiKey	46.10

Table 10: Wind Direction Sensor Evaluation

From Table 10, sensor #1 (Wind Vane) has been selected as it is low-cost and offers reasonable (IP64) protection from the elements, it also may share the RS485 bus with the selected Wind Speed sensor.

Airborne Particle Count (APC)

Airborne particulates are microscopic suspended chemical particles in air which can be inhaled into the lung [22]. When discussing APC, PM10 and PM2.5 are often used (see Table 11) and are considered as major risks to health by the World Health Organization (WHO) [23].

Airborne Particle Type	Examples
PM2.5 (<2.5 Micron)	Fossil Fuel Emissions, Smoke, Aerosol Vapours
PM10 (<10 Micron)	Dust, Smoke, Mold Spores

Table 11: Airborne Particle Examples [22]

Airborne particle count can be measured using Passive (Diffusion Tube and Deposit Guage), Biomonitoring, Optical, LIDAR and DIAL sensors. In Table 12, the optical type of sensor has been selected due to the high entry cost for the LIDAR and DIAL alternatives [24].

Part No.	Form Factor	Manufacturer	Interface	Power	IP	Vendor	Cost (£)
Next-PM #1		TERA Sensor	UART (3V3) 115200bps	5VDC	No	rs.online.co.uk TERA Sensor Next-PM RS	81.89
HPMA115 C0-003 #2		Honeywell	UART (5V) 9600bps	4.8-5.2VDC	No	rs.online.co.uk HPMA115C0-003 Honeywell, Air Quality Sensor RS	105.70
SEN0177 (Module) #3		DFROBOT (Module)	UART (5V) 9600bps	4.95-5.05VDC	No	thepihut.com Gravity: Laser PM2.5 Air Quality Sensor The Pi Hut	45.00
PMS5003 - 105770 #4		Plantower	UART (3V3) 9600bps	4.5-5.5VDC	No	thepihut.com PMS5003 Particulate Matter Sensor with Cable The Pi Hut	24.50

Table 12: APC Sensor Evaluation

From Table 12, sensor #4 has been selected due to value grounds and that it can measure PM1.0, PM2.5, and PM10 [25].

Brightness

Sunlight is the portion of the electromagnetic spectrum containing ultraviolet, infrared, and visible light [26]. Sunlight brightness is the intensity of the sunlight and measured in Lux, which at noon can reach a figure of over 100,000 Lux to a low of 0.0001 Lux on an overcast evening [27].

Sensor Type	Advantages	Disadvantages
Campbell-Stokes Sunshine Recorder	No moving parts so highly robust.	Large size, cannot be interfaced with microcontroller.
Pyranometer	Low power and wide spectral range [28]	High cost of entry
Photometer	Low power and a simple device [29]	High cost of entry
Ambient Light Sensor (ALS)	Mimic the response of the human eye to sunlight. Low power and available in IC packages [30]	Uncommon to find sensors measuring above >100,000 Lux.

Table 13: Brightness Sensor Types [28]

In Table 14, the sensors considered are of the ALS type, due to cost and availability.

Part No.	Form Factor	Manufacturer	Interface	Power	IP	Vendor	Cost (£)
PIM375 (Board) BH1745 (IC) #1		Pimoroni (Board) Rohm Semi (IC)	I2C	3.3-5VDC	N/A	Pimoroni.com BH1745 Luminance and Colour Sensor Breakout	10.50
ADA5378 (Board) VEML7700 (IC) #2		Adafruit (Board) Vishay (IC)	I2C	3-5VDC	N/A	thepihut.com Adafruit Right Angle VEML7700 Lux Sensor - I2C Light Sensor - STEMMA QT / Qwiic The Pi Hut	4.80
WS 10H #3		Jung	Analog (0-10VDC)	15-30VDC	65	KNXshoponline.co.uk Brightness sensor - WS 10 H - KNX Shop Online	129.55
SEN0562 (Module) #4		DFROBOT (Module)	I2C	3-5VDC	68	Thepihut.com Gravity: I2C IP68 Waterproof Ambient Light Sensor (1-65535lx) The Pi Hut	8.50

Table 14: Brightness Sensor Evaluation

From Table 14, the selected sensor is #4 due to its value and IP68 rating. This sensor is able to be powered from a 3.3V or 5V source and uses I2C, allowing this sensor to share the bus with other sensors.

Ultraviolet Light (UVA & UVB)

Ultraviolet light is a form of radiation and is dangerous in that it can penetrate the skin, promoting the development of skin cancer through cellular damage [31]. Of the types of UV radiation in Table 15, UVC is the most dangerous however it cannot penetrate the earth's atmosphere [32].

UV Type	Wavelength	UVB/UVB Sensor Types
UVA	315-400nm	Radiometer/Optometer
UVB	280-315nm	Photodiode: Wire Electrode Structure, Spherical Cathode Structure, Flat Cathode Structure
UVC	100-280nm	Dosimeter

Table 15: UV Radiation and Sensor Types

Within Table 16, the sensors evaluated are all Photodiode-based as this is the only type available, the others typically integrated into handheld systems and not available for standalone purchase.

Part No.	Form Factor	Manufacturer	Interface	Power	IP	Vendor	Cost(£)
SEN0540 (Board) LTR390- UV-01 (IC) #1		DFROBOT (Board) Liteon (IC)	I2C or UART	3.3- 5VDC	No	thepihut.com Gravity: LTR390 UV Light Sensor (280nm to 430nm) - I2C & UART The Pi Hut	8.00
ADA1918 (Board) GUVA- S12SD (IC) #2		Adafruit (Board) Rothner LaserTechnik (IC)	Analog	2.7- 5.5VDC	No	thepihut.com Analog UV Light Sensor Breakout - GUVA-S12SD The Pi Hut	6.50
MIKROE- 4145 (Board) GUVB- C31SM (IC) #3		Mikro- Elektronika (Board) Electro Optical Components (IC)	I2C	3.3- 5VDC	No	rs.online.co.uk MIKROE-4145 UVB Click Ultraviolet (UV) Sensor RS	24.35
AS7331- AQFM #4		AMS OSRAM	I2C	2.7- 3.6VDC	No	rs.online.co.uk AS7331-AQFM ams OSRAM, UV Light Sensor, I2C 16-Pin OLGA16 RS	12.35

Table 16: Ultraviolet Sensor Evaluation

From Table 16, the sensor selected is #2 as it has an analog output, compact size, and wide input voltage range. None of the sensors carry an IP rating, so will require an enclosure with a UVA/UVB transparent window - eliminating the use of common transparent polycarbonate enclosures [33].

Volatile Organic Compounds (VOC)

VOCs are chemical compounds, often found in household products and manufacturing which vaporise into gases. VOCs have both short-term and long-term health effects [34].

VOC Sensor Types	Advantages	Disadvantages
Photo Ionisation Detector (PID)	Give a clear visual indication of VOCs [35]	Can only detect limited range of gases, require a flame [35]
Flame Ionisation Detector (FID)	Give a clear visual indication of VOCs [35]	Can only detect limited range of gases, require a flame [35]
Metal Oxide Semiconductor (MOS)	Available on small IC packages and low power [36]	Highly sensitive, may detect short term VOCs like perfume [37]
Non-dispersive Infrared (NDIR)	Highly accurate and do not require fuel like PID/FIDs [38]	Require regular calibration and cleaning [38]

Table 17: VOC Sensor Types

In Table 18, the type considered is MOS due to the advantages in Table 17.

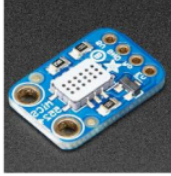
Part No.	Form Factor	Manufacturer	Interface	Power	IPxx	Vendor	Cost(£)
SGP40-D-R4 #1		Sensiron	I2C	1.7-3.6VDC	No	SGP40-D-R4 Sensiron Mouser United Kingdom	5.44
SRAQ-G020 (Board) LQ138 (Winsen) #2		L-Com (Board) Winsen (IC)	Analog or TTL	4.8-5.2VDC	No	VOC Sensor Module, 5-500 ppm, Analog and TTL level Output, MQ138 Sensi — ITM Components	109.75
ADA3199 (Board) MiCS-5524 (IC) #3		Adafruit (Board) SGX Sensortech (IC)	Analog	4.9-5.1VDC	No	Adafruit MiCS5524 CO, Alcohol and VOC Gas Sensor Breakout The Pi Hut	14.10
MICS-VZ-89TE 45 #4		Amphenol Tellaire	I2C or PWM (3V3)	3.15-3.45VDC	No	MICS-VZ-89TE 45 Amphenol Tellaire Sensors, Transducers DigiKey	24.41

Table 18: Volatile Organic Compounds Sensor Evaluation

From Table 18, the sensor selected is the SGP40-D-R4 (#1) as it has a small BOM, low cost, and uses I2C which can be shared with other sensors [39].

Memory

Memory Size

Figure 5 shows the sensor polling frequency that will be used to by the PIC to read sensor data, the Bytes/Read being the data logged.

Embedded System Generated Data						
Sensor	Freq	Logging	Bytes/R	Bytes/Min	Bytes/Day	Bytes/2Wk
GPS	14 days		32 Bytes*		4.5714286	64
Temp	60s		1 Byte	1	1440	20160
Humid	60s		1 Byte	1	1440	20160
Wind (S)	5s		2 Bytes	24	34560	483840
Wind (D)	5s		2 Bytes	24	34560	483840
Part	60s		12 Bytes	12	17280	241920
Bright	15s		2 Bytes	8	11520	161280
UV	15s		2 Bytes**	8	11520	161280
VOC	60s		2 Bytes	2	2880	40320
						1612864 Bytes/Total

Figure 5: Sensor Polling and Data Requirements

From Figure 6, an SD card has been selected as the non-volatile memory in the system. The reasoning being that SD cards are removable, like CompactFlash, but can use the serial 3.3V SPI interface, allowing straightforward connection to an 8-bit PIC, especially if the PIC is powered by 3.3VDC; SD cards are also available in large capacities, unlike SPI NAND and I2C FRAM.

Media Type	Signalling	Interface	Capacity	Pros	Cons
MicroSD/SD	1.8-3.3V	SPI/SD	2TB (SDXC) 32GB (SDHC)	Fast Large Capacity Removable	Expensive (BOM)
SPI NAND Flash	1.7-3.6V	SPI	1GB (MAX)	Fast Large Capacity	Low Power
I2C F-RAM	1.7-5.5V	I2C	128KB (MAX)	Cheap Low Pin Count	Slow High power Small size
CompactFlash	1.0-6.0V	ATA	512GB (MAX)	Robust High Performance	Expensive Requires IDE/ATA

Figure 6: Non-volatile Memory Media Evaluation

Memory Layer

An SD card requires formatting to a Windows-compatible filesystem to be read by a PC.

Filesystem	Vendor	Native OS Support	Max Disk Size
FAT16/32	Microsoft	Windows/Linux	2GB/2TB
NTFS	Microsoft	Windows/Linux/MacOS	8PB
exFAT	Microsoft	Windows, Linux, Android, MacOS	128PB

Figure 7: Comparison of SD-compatible filesystems

From Figure 7, the chosen filesystem for the PIC will be FAT16/32 due to its wide compatibility and low overhead [40]. The software will require a library to read/write to a filesystem, some options shown in Figure 8.

FAT Library	Vendor	Filesystems	Hardware Support	Requirements
FATFS	ElmChan.org	FAT16/32, exFAT	AVR, PIC, ARM, Z80, 8051	>2KB RAM
FAT.c	CCS	FAT16/32	PIC, AVR, ARM	>2KB RAM
MDD FS	Microchip	FAT16/32	PIC18, PIC24, PIC32	1.3KB RAM

Figure 8: Comparison of PIC FAT16/32 Libraries

Microchip MDD (Memory Disk Drive) has been selected as the FAT16/32 library as it offers the lowest overhead (RAM usage), whilst supporting an 8-bit PIC [41]. The SD card will use SPI to simplify communication between the PIC microcontroller and SD card, SPI is beneficial as it requires only 4 data lines (Pins) rather than the 9 for SD mode [42].

Memory Media Selection

Figure 9 shows a sample of SD cards currently available. The Swissbit SD card is selected due to the wider operating temperature and use of robust SLC NAND [43], even though it is the most expensive. The 1GB capacity of the card is also more than sufficient.

MFR Part No. / MFR	Temp	NAND	Form Factor	Capacity	Vendor	Cost
SDSDUN4-032G-GN6IN SanDisk [44]	-25°C to 85°C	TLC		32GB (SDHC) SD	Amazon UK SanDisk-Ultra-Memory-Class-UHS-I	£7.49
NT02P500STN-016G-R Netac [45]	-25°C to 85°C	TLC		16GB (SDHC) MicroSD	RS UK Netac-16GB-UHS-I-MicroSD	£3.00
SP008GBSTHBUIV10 SP Silicon Power [46]	0°C to 70°C	TLC		8GB (SDHC) MicroSD	RS UK Silicon-Power-8GB-C10-MicroSD	£5.62
SFSD1024N1AS1TO-E-DF-221-STD Swissbit [47]	-40 °C to 85 °C	SLC		1GB (SD) MicroSD	Mouser UK Swissbit-1GB-SD-SLC-MicroSD	£25.57

Figure 9: Comparison of SD Cards

Microcontroller

To ensure the SPI SD (Secure Digital) card interface is able operate within the permissible speeds of 100 - 400kHz [48], the oscillator frequency will have to be at least 400kHz (Equation 1) for an instruction speed of 100kHz (Equation 2).

$$SPI_{Clock\ Frequency} = \frac{F_{osc}}{4} \mid \frac{F_{osc}}{16} \mid \frac{F_{osc}}{64} \text{ or } \frac{TIMER2}{2}$$

Equation 1: PIC18 Hardware SPI Clock Setup [49]

$$PIC_{CPI(Clocks\ Per\ Instruction)} = \frac{CPU_{FREQ}}{4}$$

Equation 2: PIC Instruction Speed [49]

SD cards operate at 1.8-3.3V, either requiring the PIC to operate at 3.3V or the use of a level shifter for the SPI lines (SDI, SDO, SS, CLK) [50].

Device/Sensor	Bus Topology	Bus Type	Bus Count	Pin Count
USB C Port	USB	Device Mode	1	2
SD Card	SPI	Multipoint	1	4
Activity LED	N/A	N/A	N/A	1
GPS Module	I2C	Multipoint	1	2
Temperature	I2C	Multipoint	1	0*
Humidity	I2C	Multipoint	1	0*
RS485 Driver	RS485	Multipoint	1	2 (+1)**
Serial (UART)	UART	Point to Point	1	2
Brightness	I2C	Multipoint	1	0*
Ultraviolet light	Analog	10-bit ADC	1	1
VOC	I2C	Multipoint	1	0*

Figure 10: PIC I/O Interface Requirements

The PIC will function as a USB device, not as a USB host (controller)- which would otherwise require a 16-bit PIC24 [51]; the USB 1.1 interface will operate in Full-Speed mode (12Mbps/s).

The selection of an SD card, with a FAT32 filesystem, requires at least 1.3KB of SRAM available to obtain the minimum function from the FAT libraries (Figure 8), ruling out the entry-level PIC devices like the PIC16F877A, which has 368 Bytes of RAM [52]. To ensure sufficient RAM for the program components (i.e., variables) the PICs evaluated all had a minimum of 2KB (2048 Bytes) of SRAM.

The Microchip Advanced Part Selector (Figure 11) was used to identify a suitable PIC using the requirements given by Figure 10, with 27 suitable 8-bit PIC18F MCUs identified. These results were sorted by pin count (ascending), the PIC18F24J50 being selected(Figure 11) with a max operating frequency of 48MHz (at 3V3) and 3776 Bytes of SRAM [53] [54].

Figure 11: Microchip Advanced Part Selector [53]

Peripheral	Qty	Capability	Max Speed
MSSP	2	SPI (Master/Slave), I2C (Master/Slave)	1MHz (I2C), Equation 1 (SPI)
ESART	2	UART, RS485/422, RS232	Equation 1
USB	1	USB Device Only	12Mbps (Full-Speed)
Timers	5	3 x 8-bit, 2 x 16-bit	N/A

Table 19: PIC18F24J50 Peripherals [54]

The PIC18F24J50 is available in 28-pin TQFP, QFN, and DIL packages and features user-configurable ('RPn') pins which the UART2 and MSSP2 are routed through. MSSP1 is configured as I2C (MSSP2 supports only SPI), UART1 to the RS485 driver, and UART2 as RS232 [54]. As the majority of sensors use the I2C interface, I2C will be reserved for sensors and SPI used only to interface with the SD storage.

A single pin will be used for software UART (TX-only) at 9600bps, for the debugging line (Figure 67).

Figure 12: PIC18F24J50-I/ML [55]

The crystal oscillator frequency of the PIC will be set 16MHz with the FOSC/64 (Equation 1) divider used to generate an SPI clock of 250kHz. The CPU to oscillator clock will be 1:1, to give an effective CPU clock of 16MHz and instruction frequency of 4MHz (Equation 2) [54].

Package Design

Connectors

The external connectors for the system need to be robust for use in an outdoor environment, requiring gold-plated contacts, IP66, and latching/notching.

Each connector will need to pass power (+Vcc, GND) and have a fixed orientation and notch/locating pin to simplify installation/teardown. Both, circular Mil-spec/Industrial connectors meet these requirements.

Sensor	Location	Data Lines	External Power	External Pins Required
Activity LED	Internal	1	N/A	N/A
GPS	Internal	2 (I2C)	N/A	N/A
Temperature	External	2 (I2C)	5V	4
Humidity	External	2 (I2C)	5V	4
Wind Speed	External	2 (RS485)	9V	4
Wind Direction	External	2 (RS485)	9V	4
APC	Internal	2 (UART)	N/A	N/A
Brightness	External	2 (I2C)	5V	4
UV	External	1 (Analog)	5V	3
VOC	Internal	2 (I2C)	N/A	N/A

Table 20: Connector Requirements

Table 20 shows that a total of 5 external connectors are required (Temperature/Humidity is a single sensor), 4 requiring 4 pins and 1 requiring 3.

Connector	Pin Gender	Pin No.	IP-rating	Brand	Part No.	Unit Cost
	Male	4	IP68	RS PRO [56]	207-2219	£22.62
	Female	4	IP67	RS PRO [57]	207-2402	£15.30
	Male	4	IP67	RS PRO [58]	207-2390	£15.30
	Male	4	IP69K	Amphenol [59]	62GB-50T14-04PN	£67.07

Table 21: 4-Pin Connector Comparison

From Table 21, the flange-mount connector with the highlighted part number has been selected for the I2C and RS485 based external sensors.

Connector	Gender	Pin No.	IP-rating	Brand	Part No.	Unit Cost
	Female	3	IP67	RS PRO [60]	207-2398	£15.30
	Male	3	IP67	RS PRO [61]	207-2386	£15.30
	Male	3	IP69K	Amphenol [62]	62GB-50T08-33PN	£43.09
	Female	3	IP69K	Amphenol [63]	62GB-50T08-98SN	£47.09

Table 22: 3-Pin connector comparison

In Table 22 the sensor with the highlighted part number has been selected for the external Analog UV sensor.

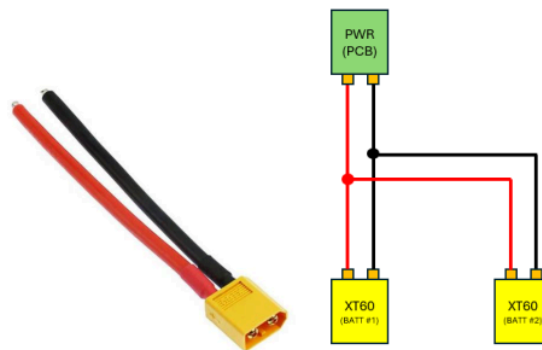


Figure 13: XT60 Parallel Battery Male Cable

Finally, a male XT60 crossover cable (Figure 13) will be used to provide power to the PCB from the two batteries in parallel configuration.

Battery

Table 23 compares the battery chemistries which may be used to power the system. Of these, the lithium chemistries have the greatest energy density, offering a significantly lower weight and size for the same energy capacity [64].

Chemistry	Nominal Cell Voltage (Typ.)	Specific Power (W/kg, typ.)	Temperature Range (Typ.)	Cycle Life (Typ.)	Energy Density (W.h/L, typ.)
Lithium Ion (Li-ion)	3.6 - 3.8V	1 – 10000	-20 to 60°C	500 – 1000 cycles	250 - 693
Lithium Polymer (Li-po)	3.6 - 3.8V	1 - 10000	-20 to 60°C	300 – 500 cycles	250 - 670
Lithium Iron Phosphate (LiFePO4)	3.2V	200 - 1200	-20 to 60°C	2500 – 12000 cycles	333
Lead Acid (Pb)	2.1V	180	-40 to 55°C	350+ cycles	60 - 75
Alkaline	1.5V	50	-18 to 55°C	N/A	250 – 434
Nickel Metal Hydride (NiMH)	1.2V	250 - 1000	-20 to 70°C	500 cycles	140 - 300
Nickel Cadmium (NiCd)	1.2V	150	-20 to 60°C	800 cycles	50 - 150

Table 23: Common Battery Chemistry Comparison [64] [65] [66]

Estimated System Power Consumption							
Component	Function	Vdd (V)	I_on (A)	I_off (A)	PWR_on (W)	PWR_off (W)	PWR_avg (ON)
MAX487	RS485 'xciever	5	5.00E-04	1.20E-04	2.50E-03	6.00E-04	9.80E-04
PIC18F24J50	Microcontroller	3.3	2.00E-02	2.00E-02	6.60E-02	6.60E-02	6.60E-02
TC1262-3.3	3V3 Regulator	9	SEE Voltage Regulators (Averaged Load)				7.18E-01
LM7805	5V Regulator	15					1.59E-01
LM7809	9V Regulator	15					4.48E-01
uSD Card	NV Storage	3.3	7.00E-02	2.50E-03	2.31E-01	8.25E-03	4.44E-02
LED	Activity LED	3.3	2.32E-02	0	7.65E-02	0.00E+00	2.32E-03
ADA4415	GPS	3.3	2.00E-02	4.00E-03	6.60E-02	1.32E-02	1.32E-02
SEN0385	Temperature	5	1.50E-03	4.00E-06	7.50E-03	2.00E-05	1.45E-04
SEN0385	Humidity	5	1.50E-03	4.00E-06	7.50E-03	2.00E-05	1.45E-04
SEN0483	Wind Speed	9	1.66E-03	1.66E-03	1.49E-02	1.49E-02	1.49E-02
SEN0482	Wind Direction	9	1.66E-03	1.66E-03	1.49E-02	1.49E-02	1.49E-02
PMS5003	APC	5	1.00E-01	2.00E-04	5.00E-01	1.00E-03	9.32E-03
SEN0562	Brightness	5	1.00E-06	1.00E-06	5.00E-06	5.00E-06	5.00E-06
ADA1918	UV	5	1.00E-06	1.00E-06	5.00E-06	5.00E-06	5.00E-06
SGP40-D-R4	VOC	3.3	3.00E-03	1.05E-06	9.90E-03	3.47E-06	1.68E-04
							1.52E-01 W (SENSOR_only)
							1.33E+00 W (INCL_vregs)

Table 24: Estimated System Power Consumption

Table 24 shows the estimated average power consumption of the system, in Watts. Two values are given, the 0.152W @ 15V and 1.33W @ 15V, the larger including the losses for the 3 linear-type voltage regulators, see Table 25, giving the estimated total power consumption.

Voltage Regulators Electrical Characteristics (Averaged Load)					
TC1262-3.3V					
VIN_max (V)	V_out (V)	I_out (A)	I_in (A)	Eff (%) @ VIN_max	
9	3.3	1.26E-01	1.26E-01	36.67	
VIN_min (V)		P_max (W)	P_min (W)	Eff (%) @ VIN_min	
9		7.18E-01	7.18E-01	36.67	
LM7805					
VIN_max (V)	V_out (V)	I_out (A)	I_in (A)	Eff (%) @ VIN_max	
15	5	1.06E-02	1.06E-02	33.33	
VIN_min (V)		P_max (W)	P_min (W)	Eff (%) @ VIN_min	
10.5		1.59E-01	1.11E-01	47.62	
LM7809					
VIN_max (V)	V_out (V)	I_out (A)	I_in (A)	Eff (%) @ VIN_max	
15	9	2.99E-02	2.99E-02	60.00	
VIN_max (V)		P_max (W)	P_min (W)	Eff (%) @ VIN_min	
10.5		4.48E-01	3.14E-01	70.00	

Table 25: Voltage Regulator Electrical Characteristics (Averaged Load)

Table 26 gives the estimated power consumption of the system as 450Wh (Watt Hours) over the 14-day operating period of the system, which is multiplied by a factor of 1.25 (see Figure 14), requiring a minimum battery capacity of 556.25Wh.

Watt Hours (14 days)		
Hrs	PWR (W)	W.H
336	1.33E+00	4.45E+02

Table 26: System Watt Hours

Table 27 compares different commercially available batteries of differing chemistries, illustrating the capacity per unit weight advantage lithium cells have. Highlighted in green is the selected battery, which is two 30Ah 3S12P (11.1V) LiPo batteries installed in parallel to form a 11.1V 60Ah (666Wh) pack, weighing only 3.8Kg when compared to the 20Kg+ of the Lead-Acid alternatives.

Brand	Part No.	Chemistry	Voltage	Capacity (Ah)	Cell Config	Dimensions (mm)	Watt Hours (W.H)	Weight (Kg)	Price
TN Power	894730	AGM Pb SLA	12.6	100	Unknown	260 x 168 x 210	1260	26	£139.69
TN Power	894639	AGM Pb SLA	12.6	75	Unknown	262 x 165 x 170	945	20	£107.03
ECO-WORTHY	UK-L13060202010-1	LiFePO4	12	100	Unknown	260 x 168 x 214	1200	10.5	£199.99
TURNIGY	9067000540-0	LiPo	11.1	8	3S2P	138 x 47 x 37	88.8	0.49	£47.12
Overlander	3022	LiPo	11.1	22	3SxP	202 x 97 x 36	244.2	1.32	£189.99
mPower	MP-100048	LiPo	11.1	40	3SxP	67 x 172 x 80	444	1.68	£132.76
OmurgA	B0DGD6DN57	LiPo	11.1	30	3S12P	111 x 67 x 120	333	1.9	£132.55

OmurgA	B0DGD6DN57	LiPo (*2)	11.1	60	3S12P(2P)	111 x 134 x 120	666	3.8	£265.1 0
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Table 27: Battery Pack Comparison

Figure 14 illustrates why the system battery capacity is multiplied by a factor of 1.25, a 3S lithium pack will drop below the critical threshold of 11V at ~20% capacity, going below the 2V dropout voltage of the LM7809 regulator, disabling the Wind Speed and Direction Sensors [67].

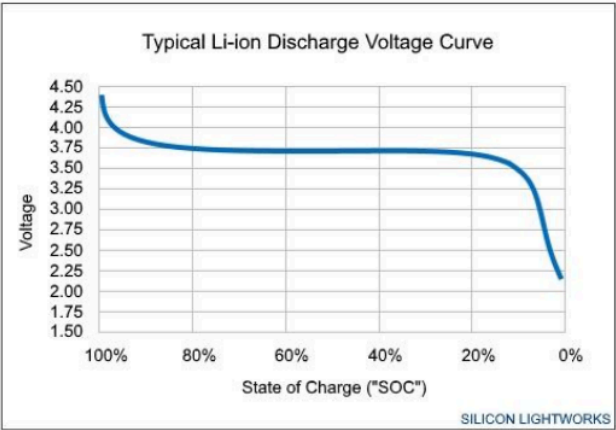


Figure 14: Lithium Cell Discharge Curve [68]

Figure 15 shows the chosen battery with included charger and XT60 discharge connector, which will require a crossover cable to allow for the two packs to run in parallel.



Figure 15: OmurgA B0DGD6DN57 11.1V 30Ah 3S12P Battery [69]

Enclosure

The enclosure for the system will need to be water-resistant to at least IP66, protecting against moisture ingress from powerful jets of rainfall, dust, and particulates [70].

The enclosure must be large enough to house a battery (for power), main control board (PCB), and hold sufficient space to mount the external connectors – whilst being sufficiently light to be portable, 4 enclosures have been evaluated in Figure 16.

Enclosure	Part No. & MFR	IPxx	Material	Dimensions	Vendor	Unit (£)
	11090501, Spelsberg #1	IP66	Plastic	130 x 130 x 99mm	RS UK Spelsberg TK PS Polystyrene Enclosure	20.47
	NSYS3D4420, Schneider Electric #2	IP66	Steel	400 x 400 x 200mm	RS UK Schneider S3D Steel Enclosure	117.30
	775-5300, RS PRO #3	IP66	Steel	300 x 250 x 150mm	RS UK RS PRO Steel Wall Box	49.92
	749-1857, RS PRO #4	IP66	Stainless Steel	150 x 150 x 80mm	RS UK RS PRO Steel Terminal Box	121.68

Figure 16: Enclosure Selection

From Figure 16, the selected enclosure is #3, which is of steel construction and IP66. It has been selected as it is sufficiently large to house the main control PCB, internal sensor modules, and battery; whilst having an access hatch allowing straightforward access to the inside.



Figure 17: IP68 Enclosure Air Vent [71]

The enclosure will have 5 holes added to the sides to mount the external connectors, which will be spaced apart to allow for easy removal of the external sensors; two additional holes will be added, one for an IP68 vent fitting at the top and bottom (to allow air into the enclosure, Figure 17 & Figure 20) to provide airflow for the internal VOC and APC sensors.

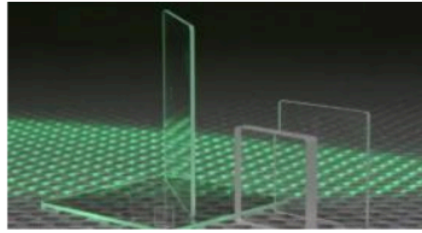


Figure 18: Fused Quartz FQP-1010 [72]

The UV sensor module will be mounted in an IP66 polycarbonate enclosure (Figure 19); however, polycarbonate blocks the entire UV spectrum [73]. A small quartz glass window (10 x 10mm) will be added to the enclosure to pass the UVA and UVB bands of the UV spectrum [74]. The quartz glass panel will be 10 x 10 mm and costs £9.00 per unit [72].



Figure 19: Polycarbonate UV Sensor Enclosure

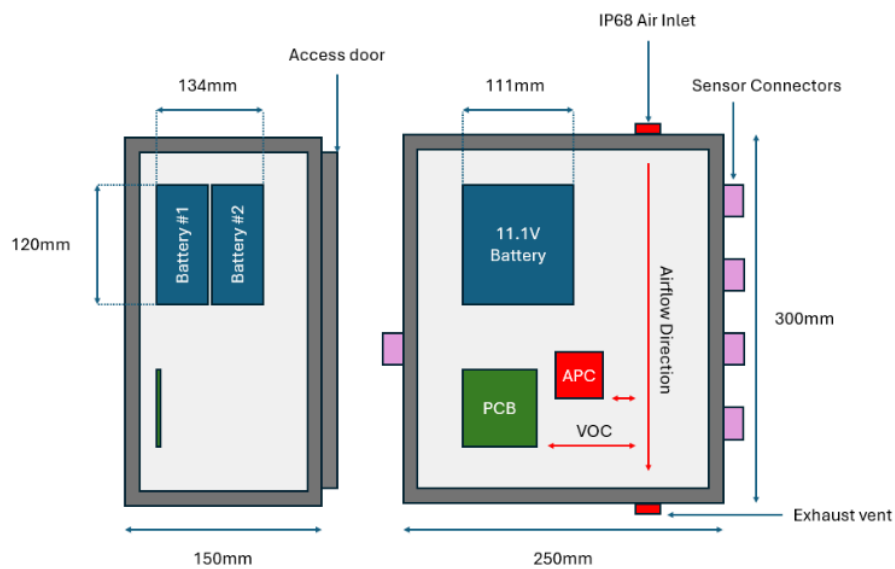


Figure 20: Hardware Enclosure Layout

Software Specification

Software Design Flowcharts

The systems operation is predominantly based off time-based interrupts, simplifying the main program and ensuring the sensors are polled accurately over the 14-day operating period of the system. A bootloader routine has been added to allow the system to transition into USB device mode and present itself to the connected PC as a USB mass storage device.

Initial Bootup Routine

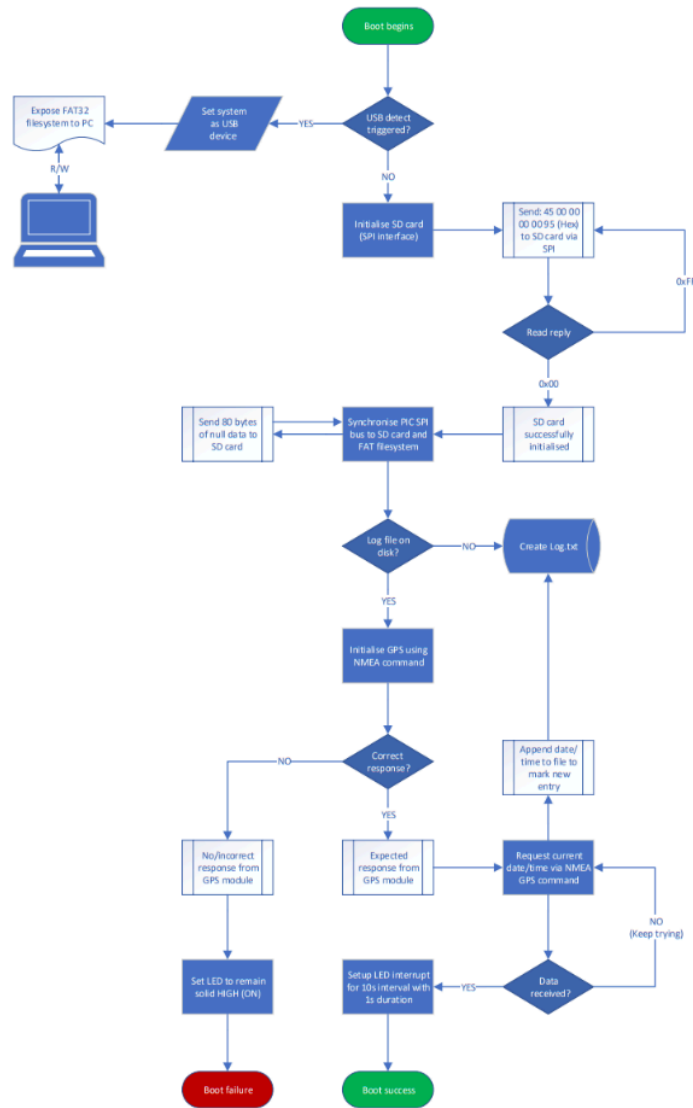


Figure 21: System Bootup Sequence

TIMER0 Interrupt Routine

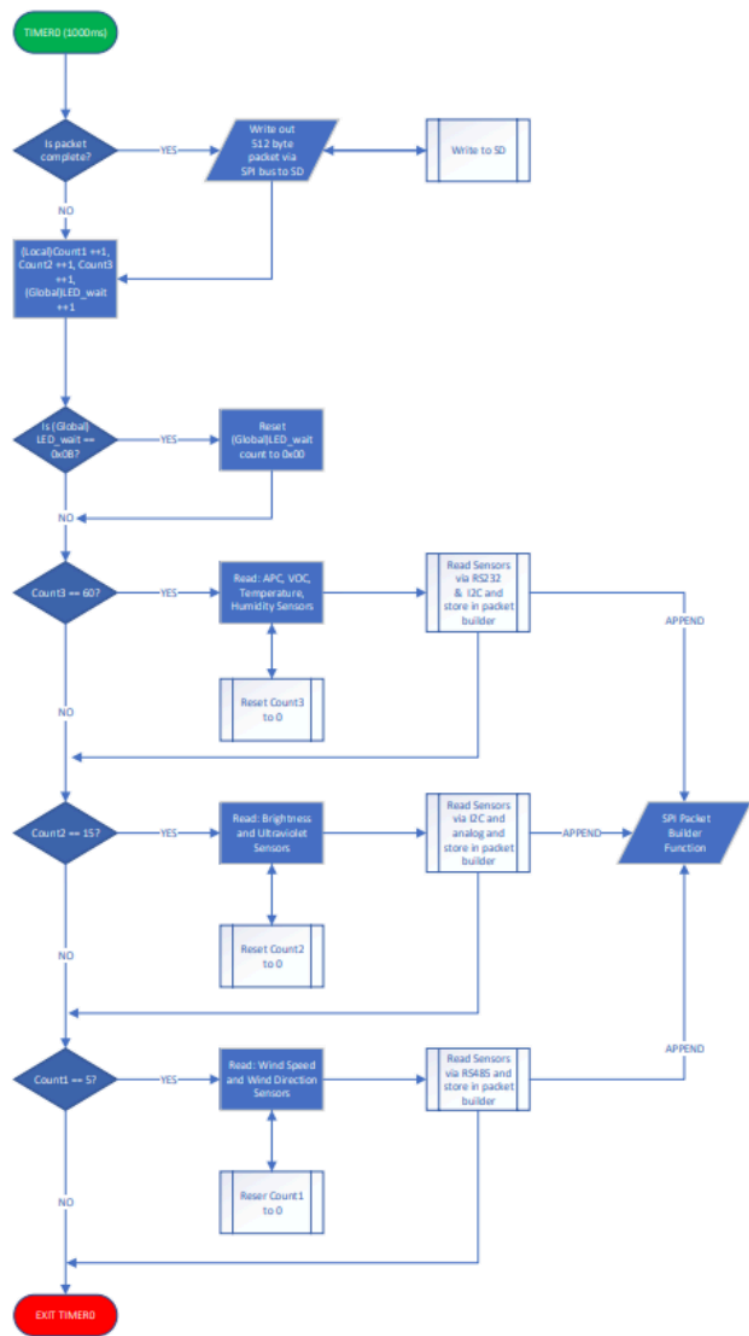


Figure 22: TIMER0 Interrupt

TIMER4 Interrupt Routine

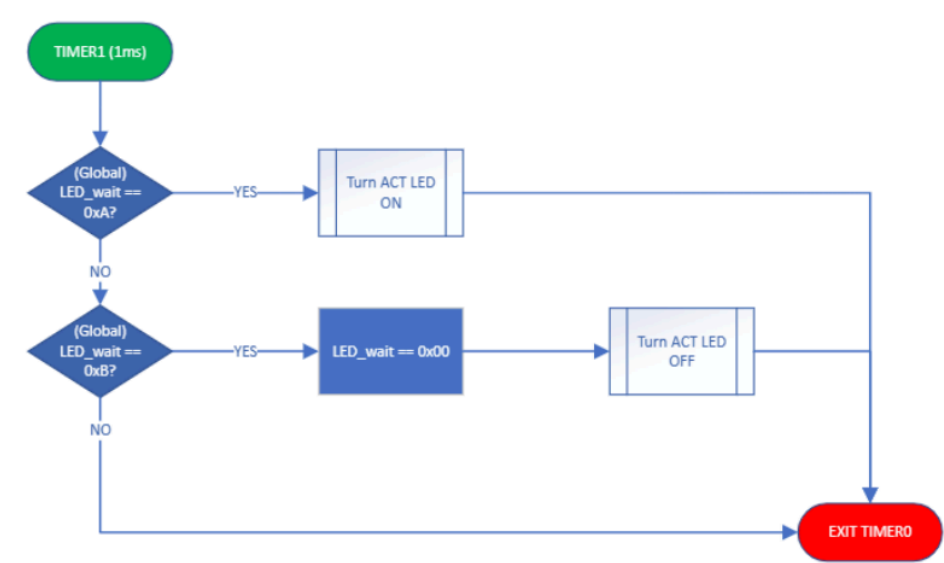


Figure 23: TIMER4 Interrupt

Main Program Routine

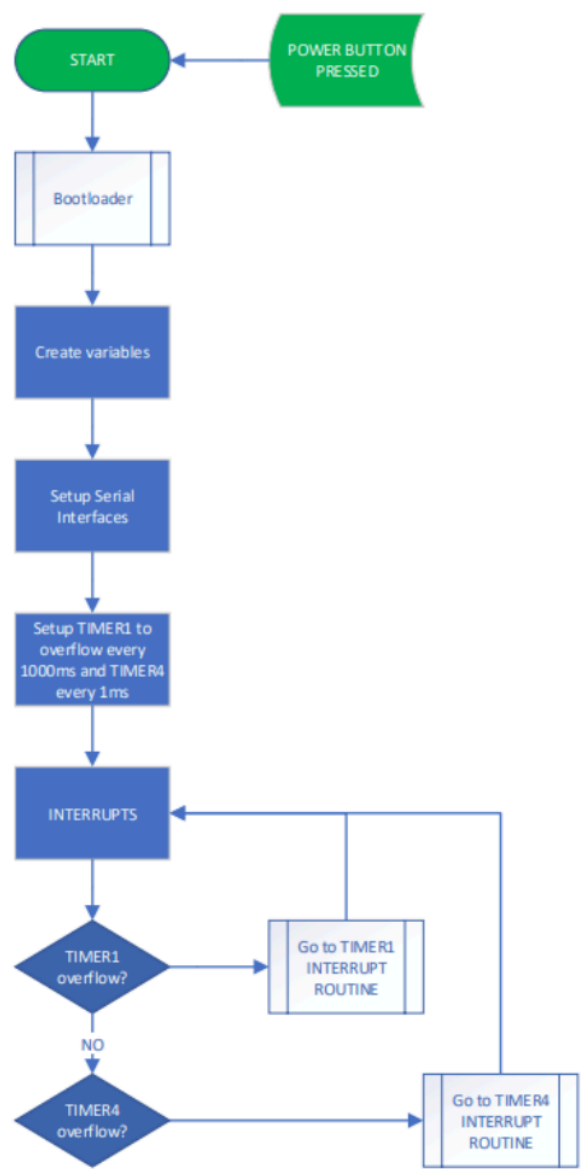


Figure 24: Main Program Loop

Software Data Structures

SD Card (SPI) Packet

Figure 25 is a partial packet, ¼ of the 512 Byte packet used to write a sector of a FAT32 format SD card. Figure 25 shows 120s (2 minutes) of logged data, with a full 512b packet consisting of 480s (8 minutes) of data.

Each 512 Byte packet will be stored in RAM, until the last byte is written. At this point the PIC will write out 512 Bytes to a memory sector in the SD card via SPI. A 512 Byte packet size has been chosen as it allows the SD card to be written sector wise, 512 Bytes being the smallest supported FAT16/32 sector size [75].

W(S)	W(S)	W(D)	W(D)	W(S)	W(S)	W(D)	W(D)	W(S)	W(S)	W(D)	W(D)	BRT	BRT	UV	UV
0x00	0x0A	0x00	0xF1	0x00	0x09	0x00	0xF1	0x00	0x0A	0x00	0xF2	0x03	0xE7	0x00	0x03
2b		2b		2b		2b		2b		2b		2b		2b	
16b															
W(S)	W(S)	W(D)	W(D)	W(S)	W(S)	W(D)	W(D)	W(S)	W(S)	W(D)	W(D)	BRT	BRT	UV	UV
0x00	0x0A	0x00	0xF1	0x00	0x09	0x00	0xF1	0x00	0x0A	0x00	0xF2	0x03	0xE7	0x00	0x03
2b		2b		2b		2b		2b		2b		2b		2b	
16b															
W(S)	W(S)	W(D)	W(D)	W(S)	W(S)	W(D)	W(D)	W(S)	W(S)	W(D)	W(D)	BRT	BRT	UV	UV
0x00	0x0A	0x00	0xF1	0x00	0x09	0x00	0xF1	0x00	0x0A	0x00	0xF2	0x03	0xE7	0x00	0x03
2b		2b		2b		2b		2b		2b		2b		2b	
16b															
W(S)	W(S)	W(D)	W(D)	W(S)	W(S)	W(D)	W(D)	W(S)	W(S)	W(D)	W(D)	BRT	BRT	UV	UV
0x00	0x0A	0x00	0xF1	0x00	0x09	0x00	0xF1	0x00	0x0A	0x00	0xF2	0x03	0xE7	0x00	0x03
2b		2b		2b		2b		2b		2b		2b		2b	
16b															
APC	APC	APC	APC	APC	APC	APC	APC	APC	APC	APC	APC	TMP	HUM	VOC	VOC
0x01	0x81	0x01	0x0F	0x00	0xFA	0x00	0xE1	0x00	0x4D	0x00	0x1E	0x10	0x35	0x00	0x54
12b (PM0.3, PM0.5, PM1.0, PM2.5, PM5.0, PM10)												1b	1b	2b	
16b															
W(S)	W(S)	W(D)	W(D)	W(S)	W(S)	W(D)	W(D)	W(S)	W(S)	W(D)	W(D)	BRT	BRT	UV	UV
0x00	0x0A	0x00	0xF1	0x00	0x09	0x00	0xF1	0x00	0x0A	0x00	0xF2	0x03	0xE7	0x00	0x03
2b		2b		2b		2b		2b		2b		2b		2b	
16b															
W(S)	W(S)	W(D)	W(D)	W(S)	W(S)	W(D)	W(D)	W(S)	W(S)	W(D)	W(D)	BRT	BRT	UV	UV
0x00	0x0A	0x00	0xF1	0x00	0x09	0x00	0xF1	0x00	0x0A	0x00	0xF2	0x03	0xE7	0x00	0x03
2b		2b		2b		2b		2b		2b		2b		2b	
16b															
W(S)	W(S)	W(D)	W(D)	W(S)	W(S)	W(D)	W(D)	W(S)	W(S)	W(D)	W(D)	BRT	BRT	UV	UV
0x00	0x0A	0x00	0xF1	0x00	0x09	0x00	0xF1	0x00	0x0A	0x00	0xF2	0x03	0xE7	0x00	0x03
2b		2b		2b		2b		2b		2b		2b		2b	
16b															

Figure 25: 1/4 of SPI Packet to SD storage

The first row of Figure 25 can be read as: 10 Knots wind speed (W(S)), 241°NW wind direction (W(D)), 999 Lux brightness (BRT) and a UV index of 3 (UV). For APC (Airborne Particle Count), 2 Bytes are read for PM0.3, PM0.5, PM1.0, PM2.5, PM5.0 and PM10 (PM10 is 0x001Eh or 30 PPM).

SD Card (SPI) Data Structure

KEY	
GPS	Global Positioning System
W(S)	Wind Speed
W(D)	Wind Direction
BRT	Brightness
UV	Ultraviolet
APC	Airborne Particle Count
TMP	Temperature
HUM	Humidity
VOC	Volatile Organic Compounds

Figure 26: SD card data structure key

For Figure 27, the GPS location is given in ASCII characters. The GPS data is stored between offset 0x00000020 and 0x00000040 can be read as, 09:16:26:00 (Hr, Min, Sec (Time)), 2236.2791N (Latitude), 12017.2818E (Longitude), 0008.8 (Metres (Elevation)) [76].

ADDRESS OFFSET	HEXADecimal	ASCII HEADER & GPS DATA
0x00000000	0x01 0x0A 0x44 0x41 0x54 0x43 0x00 0x25 0x54 0x41 0x52 0x51 0x00 0x00 0x0A 0x03	STX LF D A T A NUL S T A R T NUL CR LF
0x00000010	0x02 0x0A 0x47 0x50 0x53 0x00 0x44 0x41 0x54 0x41 0x00 0x00 0x00 0x00 0x00 0x0A	STX LF G P S NUL D A T A NUL NUL NUL NUL CR LF
0x00000020	0x30 0x39 0x31 0x38 0x32 0x36 0x30 0x30 0x32 0x32 0x30 0x32 0x37 0x38 0x31	0 9 1 6 2 6 0 0 2 2 3 6 2 7 9 1
0x00000030	0x4F 0x31 0x32 0x39 0x31 0x37 0x32 0x38 0x31 0x38 0x30 0x39 0x30 0x38 0x38	N 1 7 2 8 1 8 0 0 8 8
0x00000040	0x0A 0x45 0x4E 0x53 0x00 0x47 0x50 0x52 0x00 0x44 0x41 0x54 0x41 0x00 0x00 0x0A	LF E N D NUL G P S NUL D A T A NUL CR LF
...	...	...
0x00000200	0x00 0x0A 0x00 0x01 0x00 0x09 0x00 0x01 0x00 0x0A 0x00 0x02 0x03 0x07 0x00 0x03	10 241 9 241 10 242 999 3
0x00000210	0x00 0x0A 0x00 0x02 0x00 0x09 0x00 0x01 0x00 0x0A 0x00 0x02 0x03 0x07 0x00 0x03	10 242 9 17 9 18 999 3
0x00000220	0x00 0x0B 0x00 0x03 0x00 0x08 0x00 0x0F 0x00 0x0C 0x00 0x02 0x03 0x07 0x00 0x03	11 243 11 243 12 242 999 3
0x00000230	0x00 0x0A 0x00 0x01 0x00 0x09 0x00 0x01 0x00 0x0A 0x00 0x01 0x03 0x07 0x00 0x03	10 241 9 241 10 241 999 3
0x00000240	0x01 0x81 0x01 0x0F 0x00 0x0A 0x00 0x01 0x00 0x0A 0x00 0x14 0x10 0x43 0x00 0x04	385 271 250 225 77 31 16 84
0x00000250	0x00 0x0A 0x00 0x01 0x00 0x09 0x00 0x01 0x00 0x0A 0x00 0x02 0x03 0x07 0x00 0x03	10 241 9 241 10 242 999 3
0x00000260	0x00 0x0A 0x00 0x01 0x00 0x09 0x00 0x01 0x00 0x0A 0x00 0x02 0x03 0x07 0x00 0x03	10 241 9 241 10 242 999 3
0x00000270	0x00 0x09 0x00 0x01 0x00 0x09 0x00 0x01 0x00 0x0A 0x00 0x02 0x03 0x07 0x00 0x03	9 241 9 241 9 242 999 3
0x00000280	0x00 0x09 0x00 0x01 0x00 0x09 0x00 0x01 0x00 0x0A 0x00 0x02 0x03 0x07 0x00 0x03	9 241 9 241 10 242 999 3
0x00000290	0x00 0x0A 0x00 0x01 0x00 0x09 0x00 0x01 0x00 0x0A 0x00 0x02 0x03 0x07 0x00 0x03	10 241 9 241 10 242 999 3
0x000002A0	0x00 0x09 0x00 0x02 0x00 0x09 0x00 0x02 0x00 0x0A 0x00 0x01 0x03 0x07 0x00 0x03	9 242 9 242 9 241 999 3
0x000002B0	0x00 0x0A 0x00 0x01 0x00 0x09 0x00 0x01 0x00 0x0A 0x00 0x01 0x03 0x07 0x00 0x03	10 241 9 241 10 241 999 3
0x000002C0	0x01 0x85 0x01 0x1F 0x00 0x0A 0x00 0x01 0x00 0x0A 0x00 0x1F 0x10 0x43 0x00 0x03	389 287 250 227 77 31 16 83
0x000002D0	0x00 0x0A 0x00 0x01 0x00 0x09 0x00 0x01 0x00 0x0A 0x00 0x02 0x03 0x07 0x00 0x03	10 241 10 241 10 241 999 3
0x000002E0	0x00 0x0A 0x00 0x02 0x00 0x09 0x00 0x01 0x00 0x0A 0x00 0x02 0x03 0x07 0x00 0x03	10 241 10 241 10 241 999 3
0x000002F0	0x00 0x0A 0x00 0x01 0x00 0x09 0x00 0x01 0x00 0x0A 0x00 0x02 0x03 0x07 0x00 0x03	10 241 10 241 10 241 999 3
0x00000300	0x00 0x0A 0x00 0x01 0x00 0x09 0x00 0x01 0x00 0x0A 0x00 0x02 0x03 0x07 0x00 0x03	10 241 10 241 10 241 999 3
0x00000310	0x00 0x0A 0x00 0x01 0x00 0x09 0x00 0x01 0x00 0x0A 0x00 0x02 0x03 0x07 0x00 0x03	10 241 10 241 10 241 999 3
0x00000320	0x00 0x0A 0x00 0x01 0x00 0x09 0x00 0x01 0x00 0x0A 0x00 0x02 0x03 0x07 0x00 0x03	10 241 10 241 10 241 999 3
0x00000330	0x00 0x0A 0x00 0x01 0x00 0x09 0x00 0x01 0x00 0x0A 0x00 0x02 0x03 0x07 0x00 0x03	10 241 10 241 10 241 999 3
0x00000340	0x00 0x0A 0x00 0x01 0x00 0x09 0x00 0x01 0x00 0x0A 0x00 0x02 0x03 0x07 0x00 0x03	10 241 10 241 10 241 999 3
0x00000350	0x00 0x0A 0x00 0x01 0x00 0x09 0x00 0x01 0x00 0x0A 0x00 0x02 0x03 0x07 0x00 0x03	10 241 10 241 10 241 999 3
0x00000360	0x00 0x0A 0x00 0x01 0x00 0x09 0x00 0x01 0x00 0x0A 0x00 0x02 0x03 0x07 0x00 0x03	10 241 10 241 10 241 999 3
0x00000370	0x00 0x0A 0x00 0x01 0x00 0x09 0x00 0x01 0x00 0x0A 0x00 0x02 0x03 0x07 0x00 0x03	10 241 10 241 10 241 999 3
...	...	...
0x0018A040	0x02 0x0A 0x47 0x50 0x53 0x00 0x44 0x41 0x54 0x41 0x00 0x00 0x00 0x00 0x00 0x0A	STX LF G P S NUL D A T A NUL NUL NUL NUL CR LF
0x0018A050	0x30 0x39 0x31 0x38 0x32 0x36 0x30 0x30 0x32 0x32 0x30 0x32 0x37 0x38 0x31	0 9 1 6 2 6 0 0 2 2 3 6 2 7 9 1
0x0018A060	0x4F 0x31 0x32 0x39 0x31 0x37 0x32 0x38 0x31 0x38 0x30 0x39 0x30 0x38 0x38	N 1 7 2 8 1 8 0 0 8 8
0x0018A070	0x0A 0x45 0x4E 0x53 0x00 0x47 0x50 0x52 0x00 0x44 0x41 0x54 0x41 0x00 0x00 0x0A	LF E N D NUL G P S NUL D A T A NUL CR LF
...	...	...
0x0018A080	0x01 0x0A 0x00 0x45 0x4E 0x44 0x00 0x0F 0x46 0x00 0x46 0x49 0x4C 0x45 0x00 0x16	STX LF NUL E N D NUL O P NUL A T T E N T I O N

Figure 27: SD Card (SPI) Data Structure

Figure 27 shows a 384 Bytes of a 512 Byte sector on the SD card, showing the structure of the data stored. GPS data is stored in the first sector and last sector of memory on the SD card, respectively preceded and sub seeded by the header and end of file ASCII strings, each of which are 16 Bytes long.

Hardware Design

Circuit Block Diagram

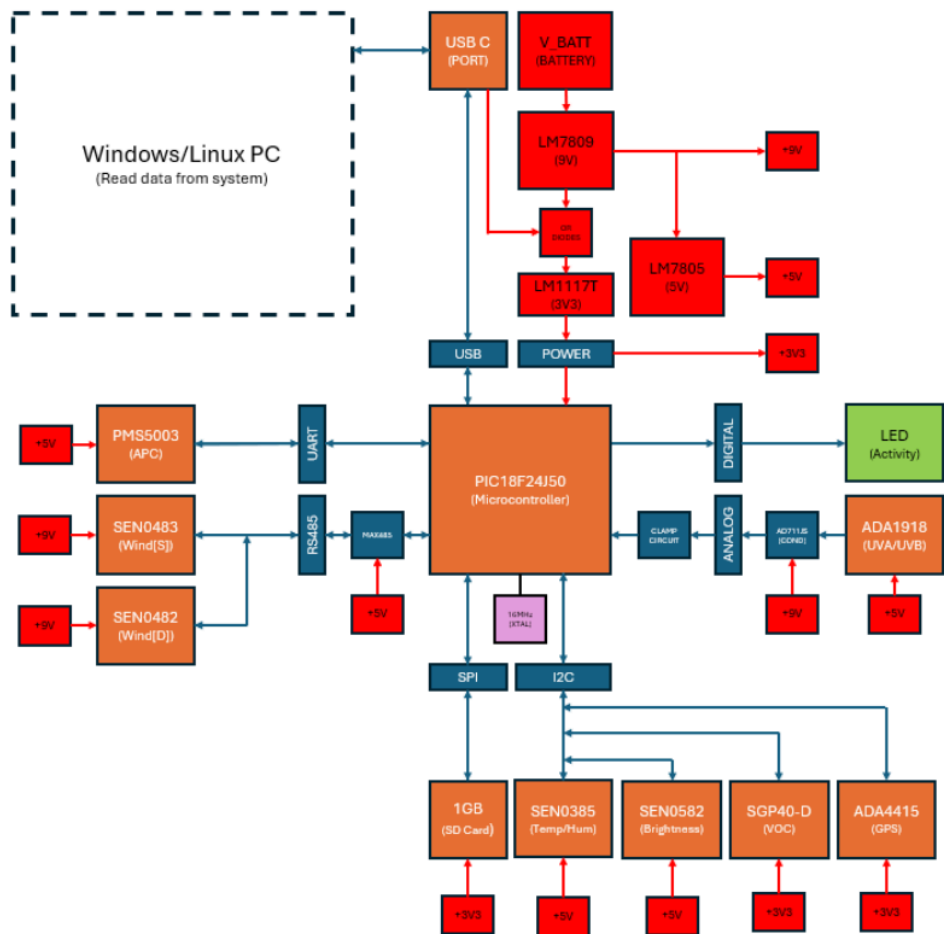


Figure 28: Advanced Circuit Block Diagram

Software Setup (CCS)

This section covers the setup and layout of a circuit schematic in Proteus and Easy PC, with the CCS PICC-C software used to aid creation of the Proteus project.

CCS is used to generate the header files and configure interfaces (i.e., UART, SPI, I2C) which are used for sensors on the system.

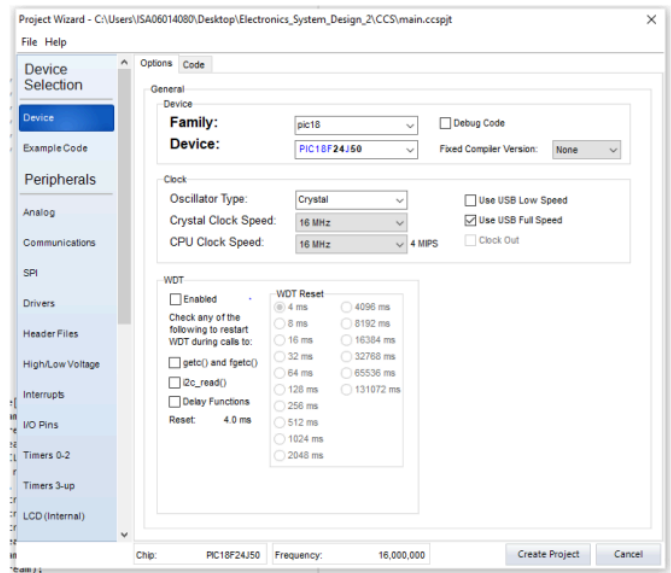


Figure 29: PIC Clock Setup (CCS)

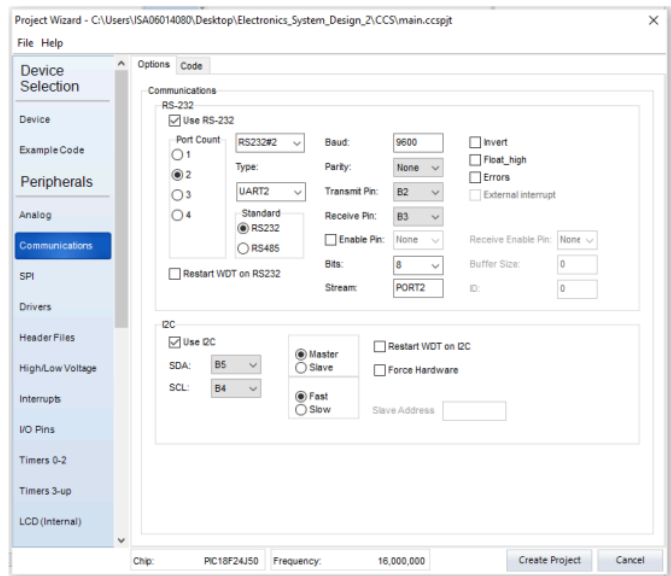


Figure 30: I2C/UART2 (RS232) Setup (CCS)

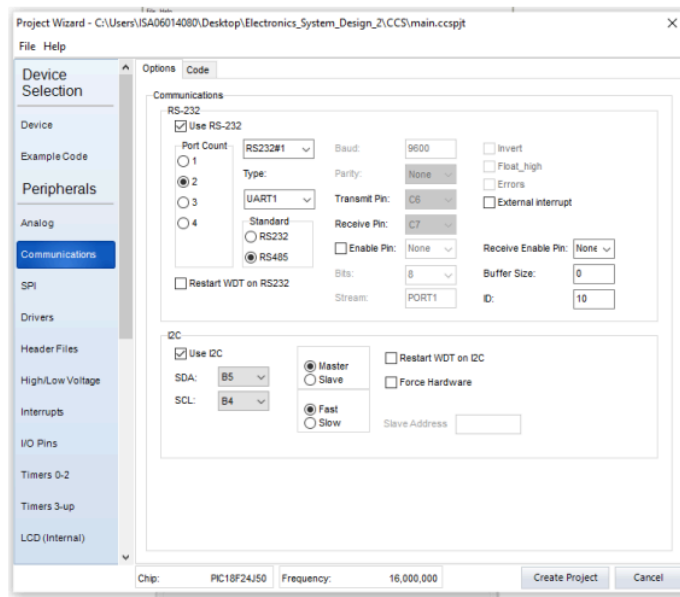


Figure 31: PIC I2C/UART1 (RS485) Setup (CCS)

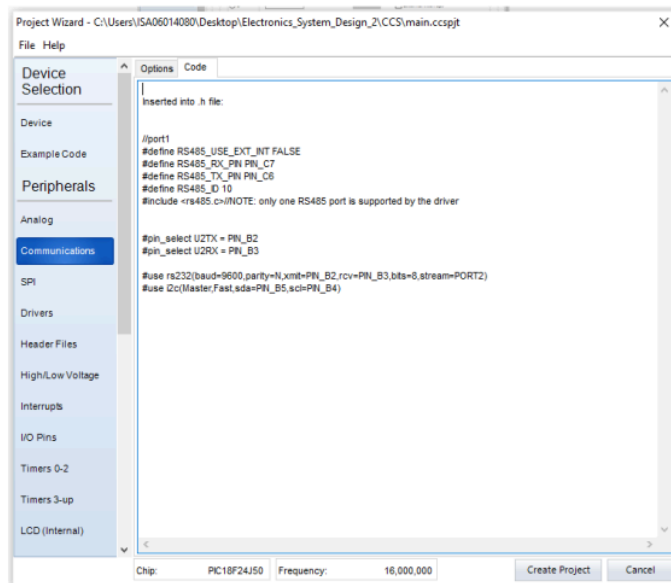


Figure 32: PIC I2C/UART1 & UART2 Setup Code (CCS)

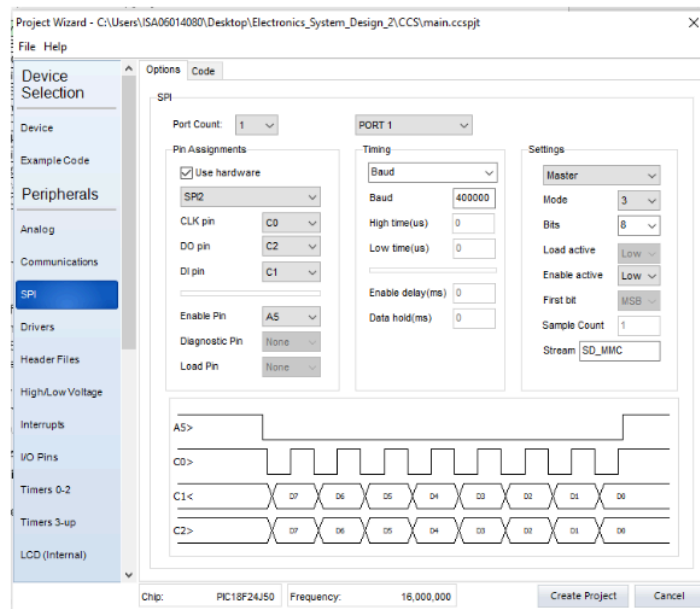


Figure 33: PIC SPI2 (SD Card) Setup (CCS)

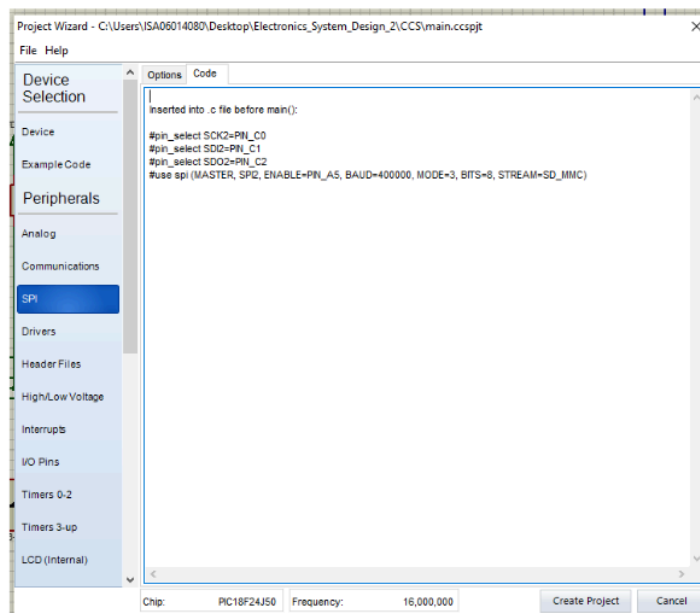


Figure 34: PIC SPI2 (SD Card) Setup Code (CCS)

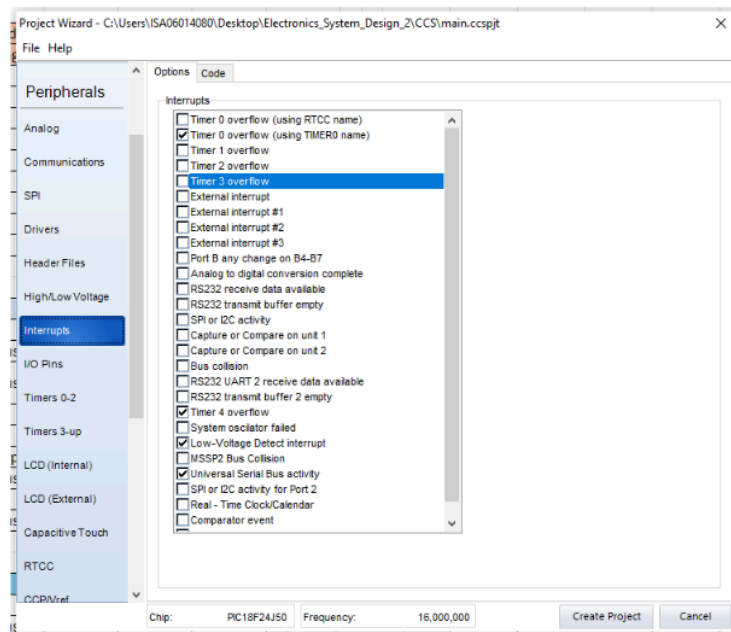


Figure 35: PIC Interrupt Setup #1 (CCS)

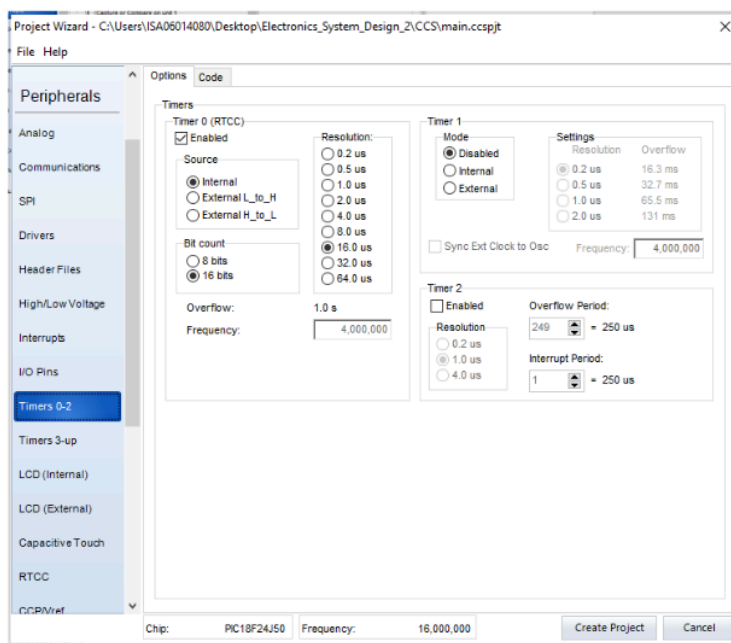


Figure 36: PIC Interrupt TIMER0 Setup (CCS)

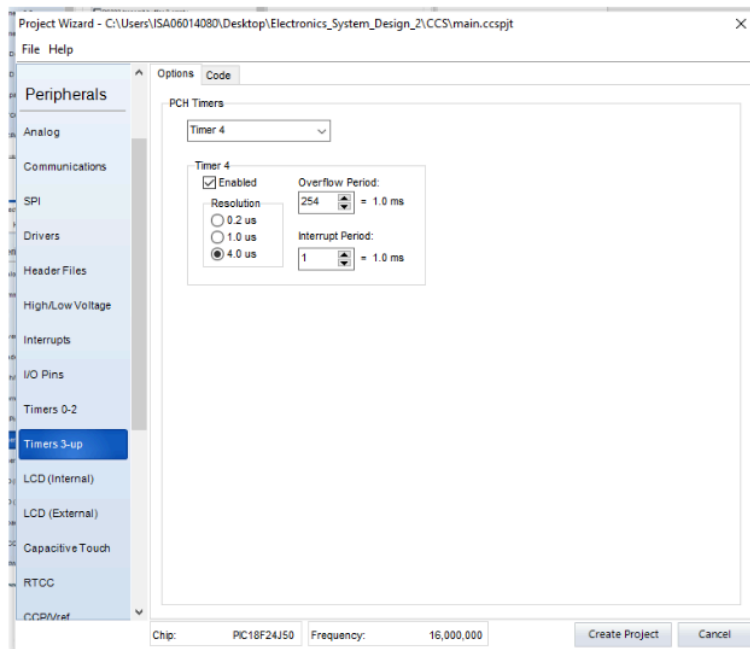


Figure 37: PIC Interrupt TIMER4 Setup (CCS)

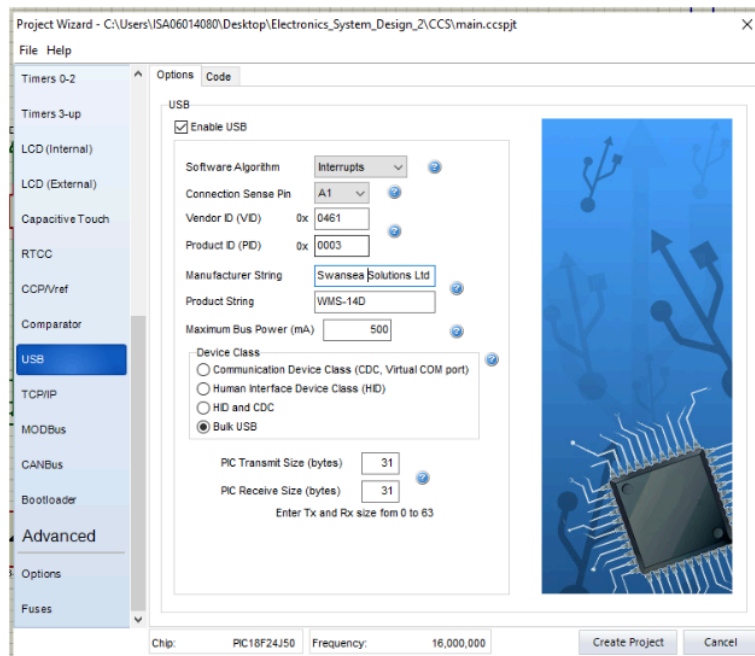


Figure 38: PIC USB Interface Setup (CCS)

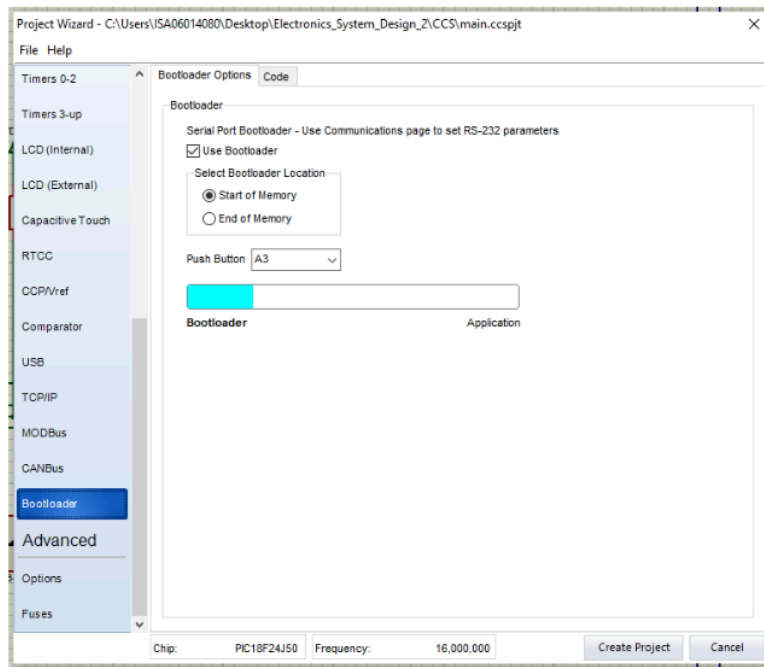


Figure 39: PIC Bootloader Setup (CCS)

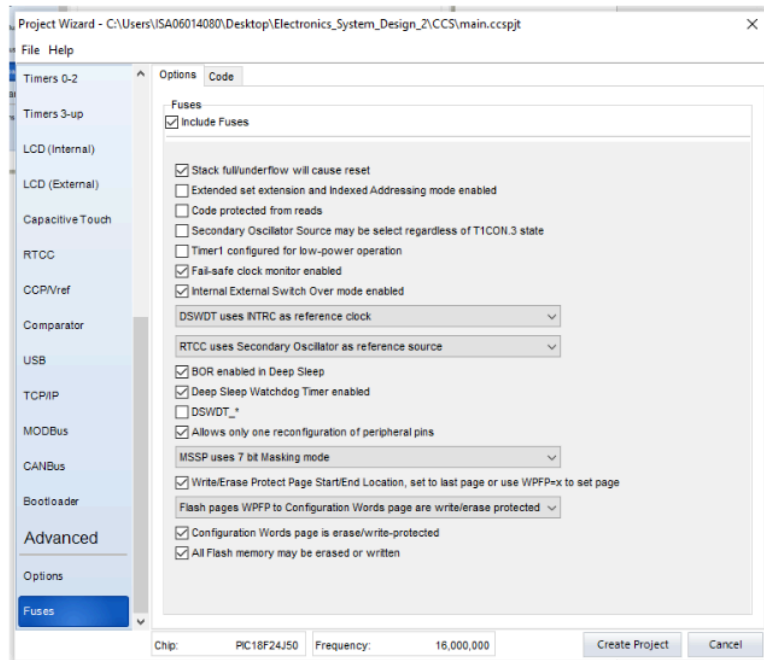


Figure 40: PIC Fuses Setup Code (CCS)

Circuit Schematics (Proteus & Easy-PC)

This section covers the use of circuit design software (Proteus & Easy-PC) to inform the design of a PCB. The proteus design covers the basic hardware operation, with the Easy-PC schematic including connectors and greater detail as it forms the basis of the PCB design.

Circuit Schematic (Proteus)

The circuit schematic has been split into function blocks to simplify schematic layout.

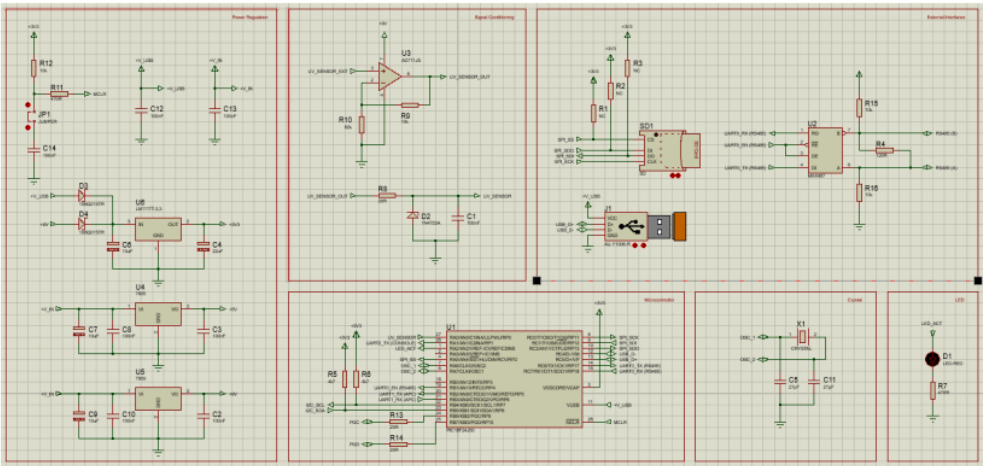


Figure 41: Circuit Schematic Overview (Proteus)

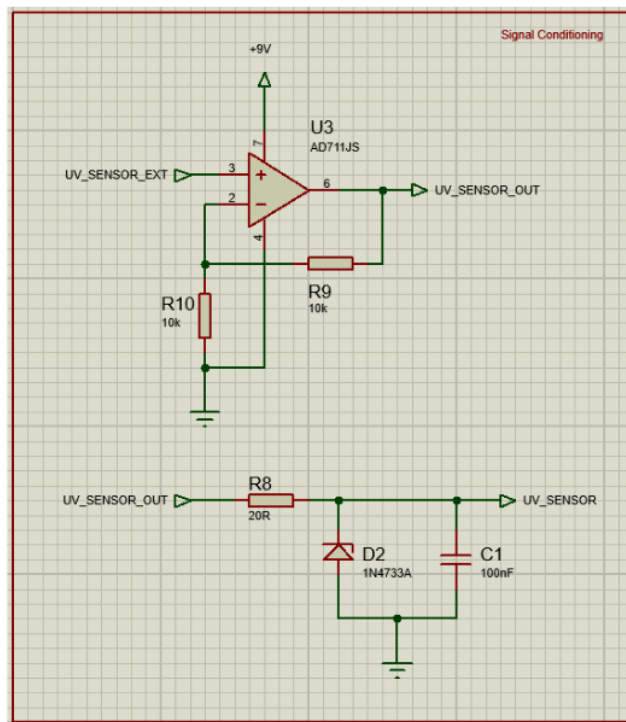


Figure 42: Circuit Signal Conditioning Block (Proteus)

Figure 42 shows signal conditioning used for the UV sensor, which has an analog output. The UV sensor output is up to 4.3V, so conditioning is added to raise the signal to ~5V and a Zener diode clamp (1N4733A) to ensure the signal does not exceed 5.1V.

Figure 43 is the voltage regulation block for the circuit, which consists of 3 voltage regulators for +9V (LM7809), +5V (LM7805), and +3V3 (LM1117-3.3) – paired with appropriately-sized smoothing capacitors to reduce ripple. The LM1117-3.3 has two schottky diodes (10BQ015TR) in an OR configuration to allow supply from either +V_USB or the +9V from the LM7809 output. If both are connected, power will be sourced from the +9V supply and isolated from the USB supply.

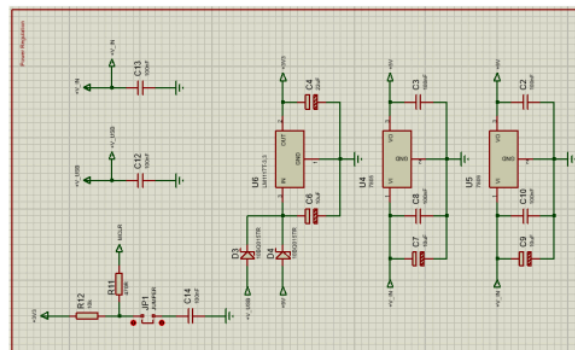


Figure 43: Circuit Voltage Regulation Block (Proteus)

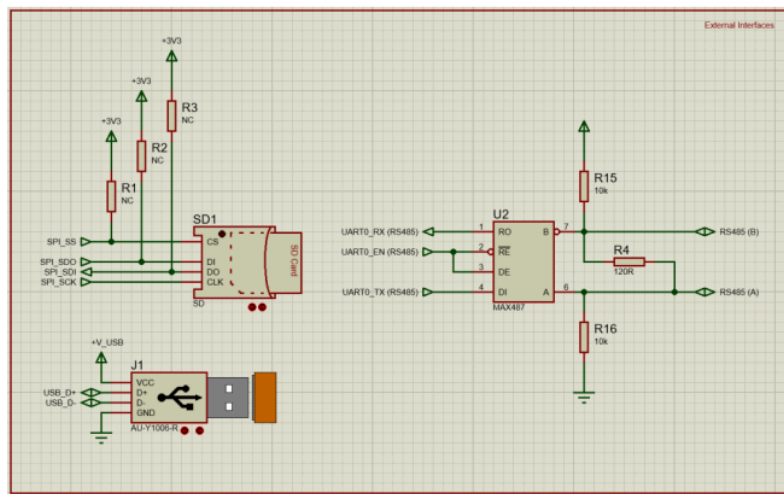


Figure 44: Circuit SPI SD Card, RS485, and USB Interface Block (Proteus)

Figure 44 and Figure 45 show the setup of the Microcontroller interfaces to the external sensors. Pull-up and pull-down resistors of appropriate values have been added to stabilise/enable proper operation of the RS485, SPI, and I2C buses.

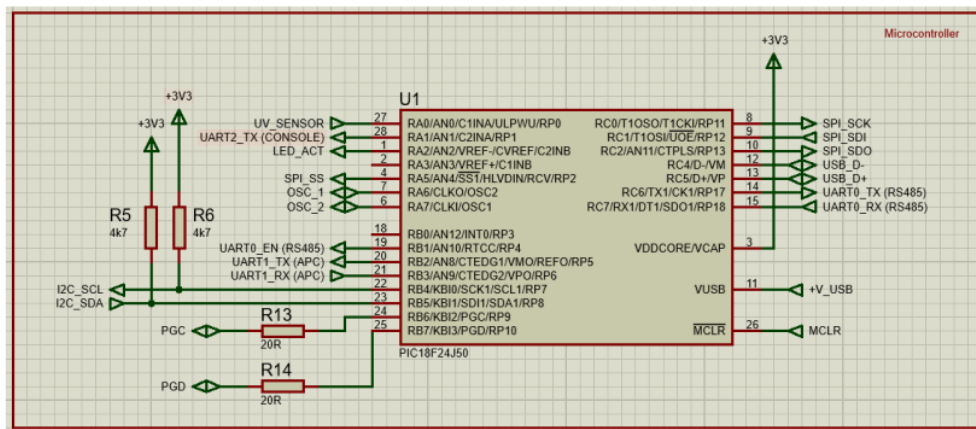


Figure 45: Circuit Microcontroller Block (Proteus)

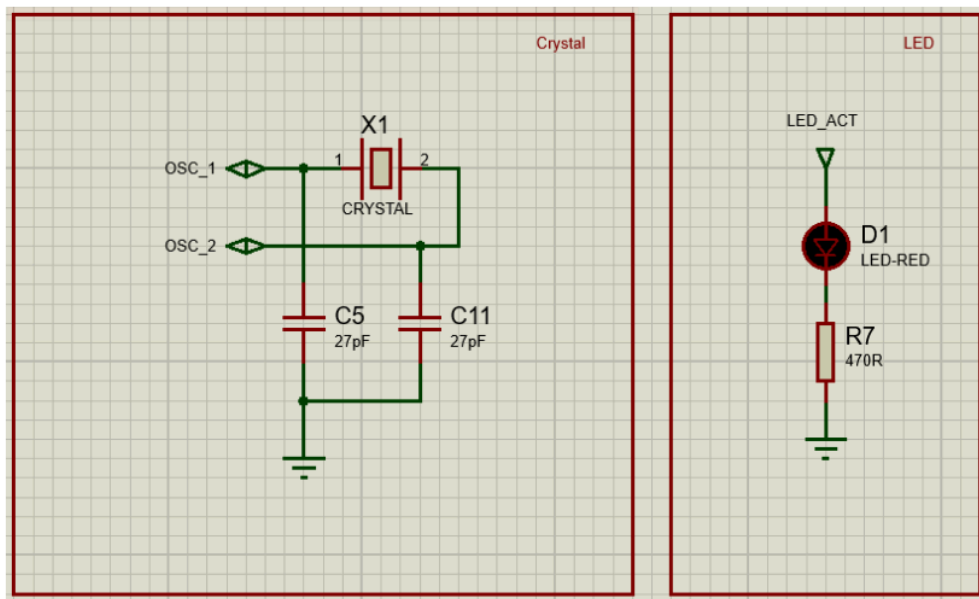


Figure 46: Circuit 16MHz Crystal and LED Block (Proteus)

Circuit Schematic (Easy PC)

This section contains the same schematics as the Proteus section, additional components added for the +Vcc/GND lines which are obfuscated on Proteus.

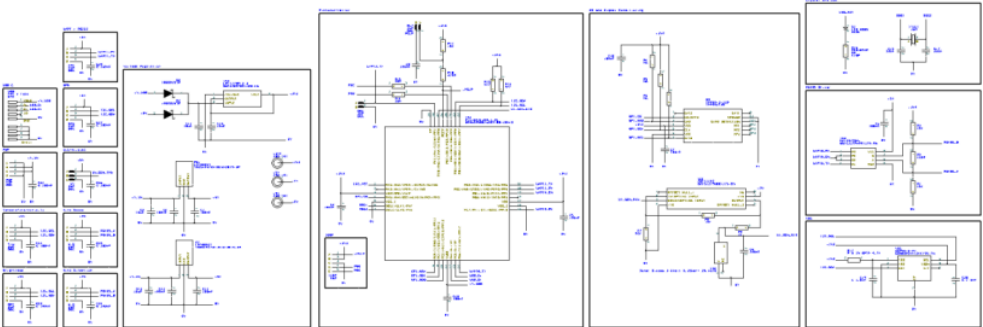


Figure 47: Circuit Schematic Overview (Easy-PC)

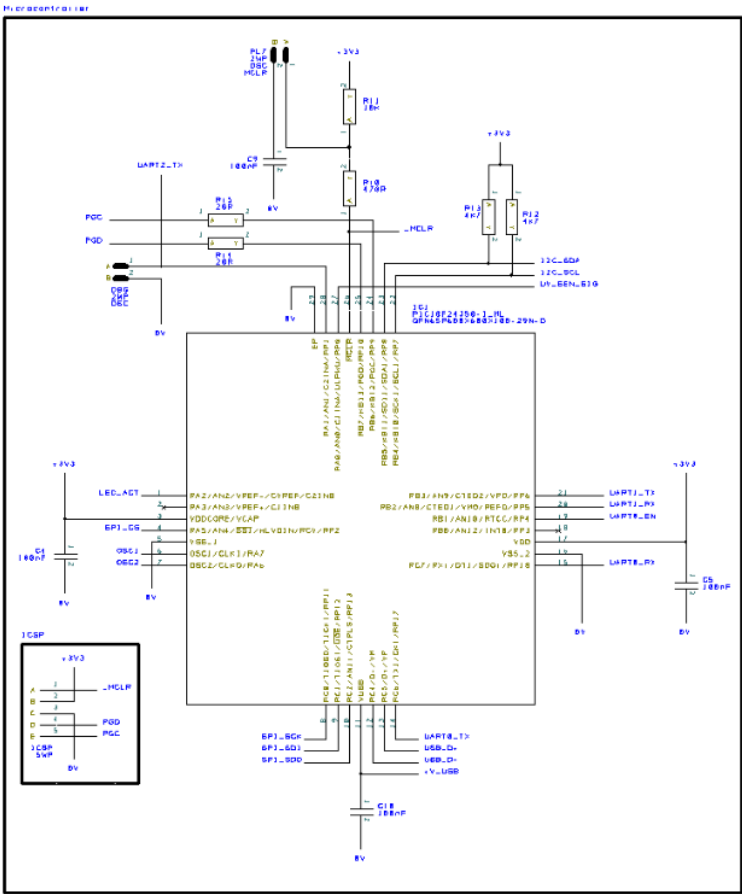


Figure 48: Circuit Microcontroller Block (Easy-PC)

RS485 Driver

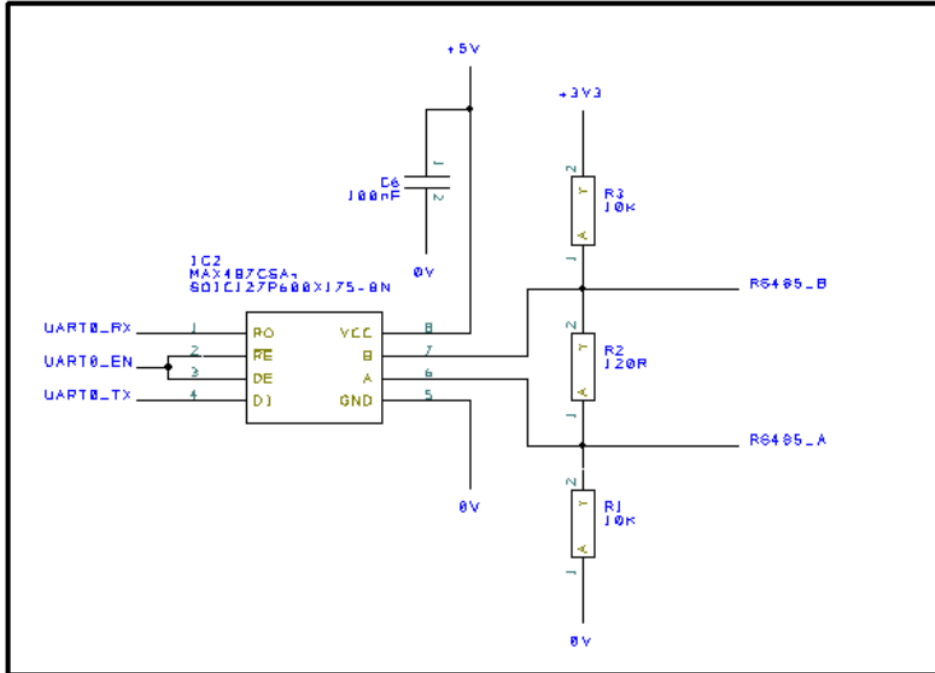


Figure 51: Circuit Schematic RS485 Driver Block (Easy-PC)

Crystal and LED

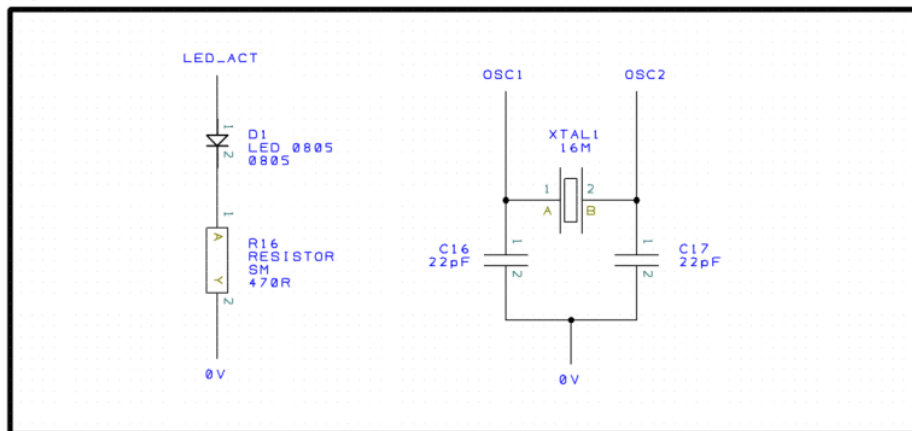


Figure 52: Circuit activity LED and Crystal Block (Easy-PC)

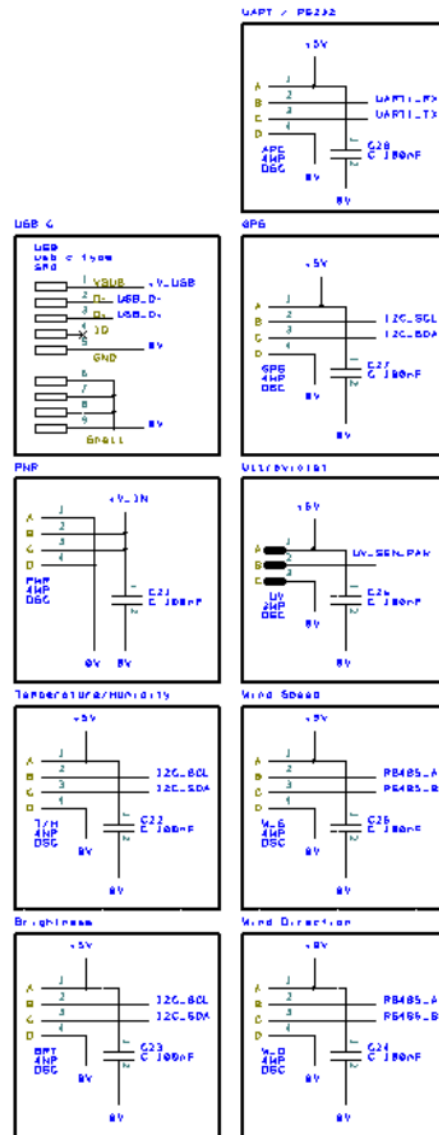


Figure 53: Circuit External Connector Block (Easy-PC)

SD and Signal Conditioning

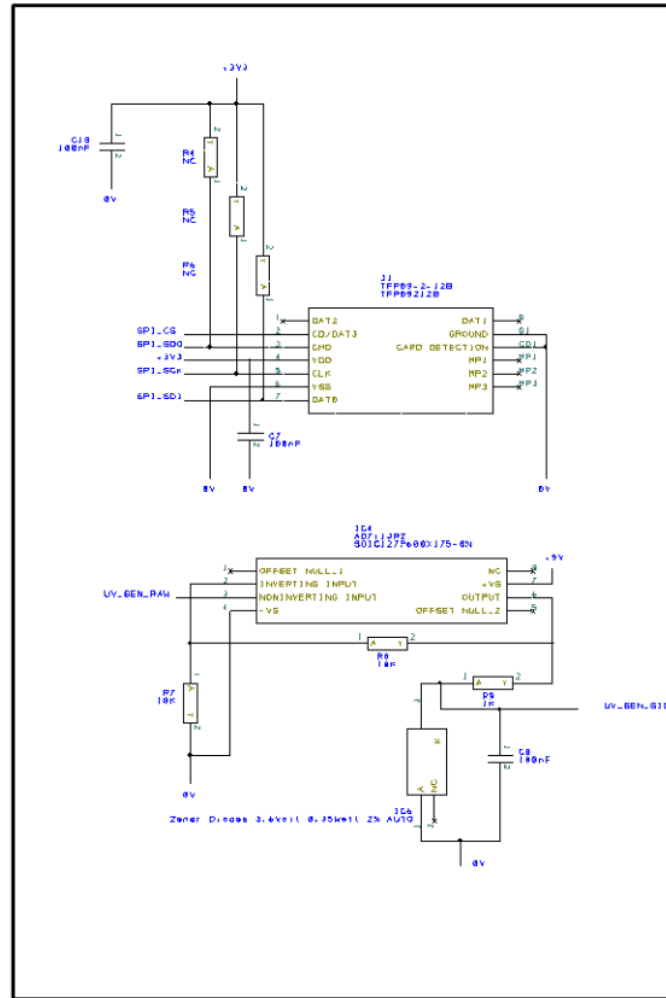


Figure 54: Circuit SD Card & Op Amp Block (Easy-PC)

PCB Design (Easy-PC)

This section covers the design of a PCB utilising the Easy-PC circuit schematics. A PCB has been implemented as PCBs are far more robust and reliable than breadboard and offer superior signal integrity for SPI, USB, UART and I2C when compared to breadboard or stripboard/Veroboard [77].

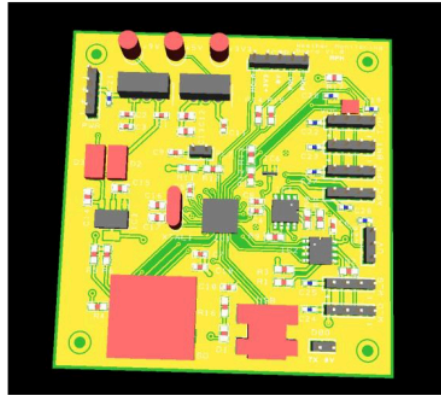


Figure 55: PCB Design 3D View (Easy-PC)

The PCB comprises of 4-layers: Mixed Signalling & Power (Top Copper), +3V3 (Internal 1), 0V/GND (Internal 2) and Mixed Signalling and Power (Bottom Copper). Minor adjustments were made to the minimum pad clearances, this being reduced from 0.25mm to 0.15mm, in line with the IPC 2221 voltage and spacing standards [78].

The physical dimensions of the PCB are 66.04mm x 68.58mm x 1.6mm, with 4x M2 mounting holes spaced 58mm equidistant. The track width for the power traces to external sensors are 0.64mm, the signalling traces 0.25mm wide. Surface mount components have been used to reduce PCB size and overall cost, along with the use of a micro-SD connector (most SD cards are the micro-SD type [79] [80]).

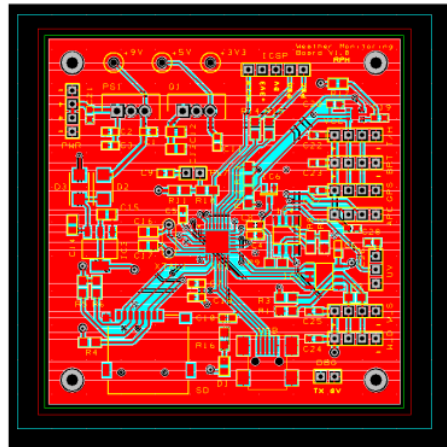


Figure 56: PCB Design 2D View (Easy-PC)

Figure 57 shows the DRC setup. All options are ticked, barring 'Acid Traps', 'Min Track Neck Length', and 'Drill Backout' as these are no longer applicable to modern PCB manufacture [81].

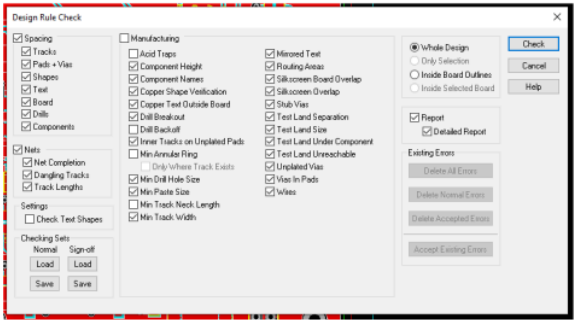


Figure 57: PCB Design DRC Options (Easy-PC)

Figure 58 is the DRC output, showing that no errors have been found – allowing for PCB plotting.



Figure 58: PCB Design DRC Result (Easy-PC)

Figure 59 and Figure 60 cover the setup for the plotting of the Gerber files used to manufacture the PCB design, Gerber being the de-facto standard used for PCB manufacture [82].

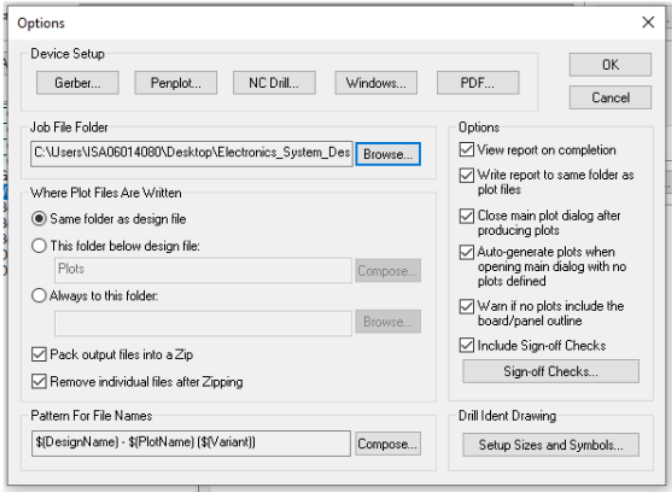


Figure 59: PCB Design Gerber Output Setup #1 (Easy-PC)

In Figure 60 the board outline has been added to the PCB layers so that it is plotted.

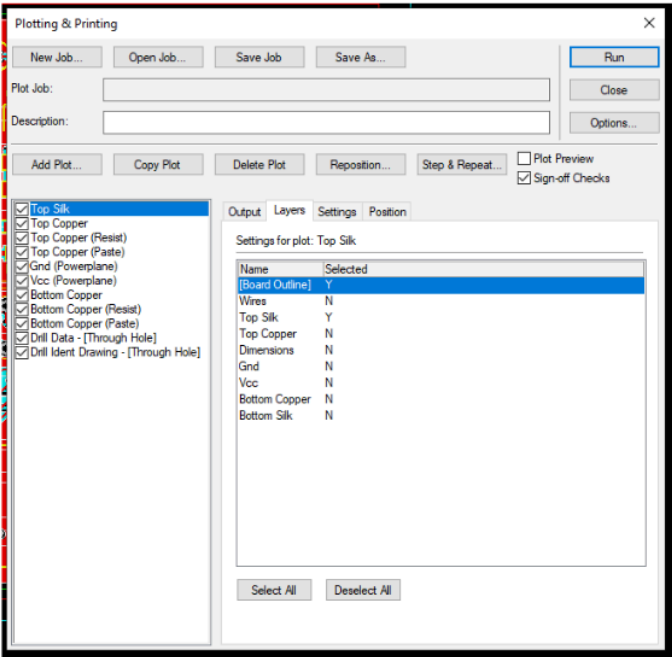


Figure 60: PCB Design Gerber Output Setup #2 (Easy-PC)

Figure 61 and Figure 62 show the outputted Gerber files saved into a zipped folder, named 'ESD2'.

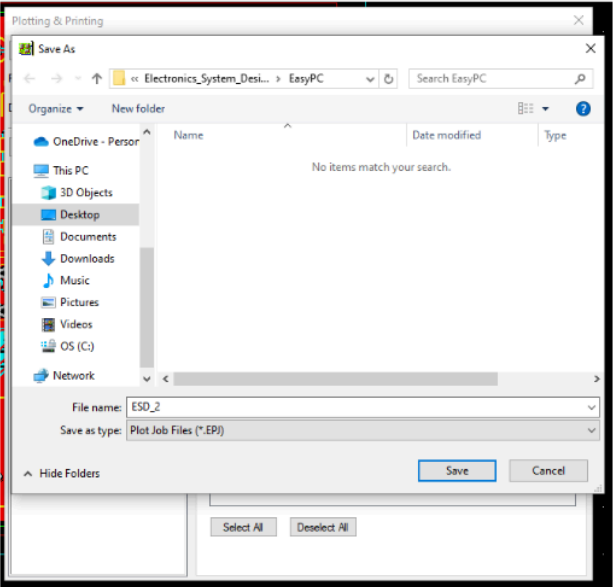


Figure 61: PCB Design Gerber Output (Easy-PC)

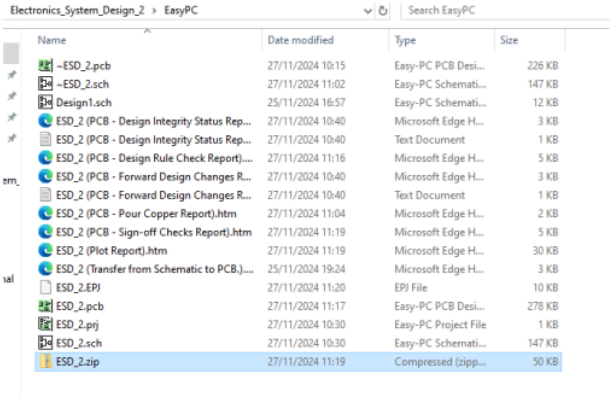
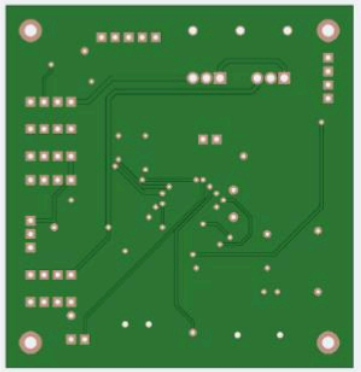


Figure 62: PCB Design Gerber Output Folder (Easy-PC)

PCB Manufacture

Figure 63 is the Gerber files uploaded to JLCPCB, providing a build cost of £5.56 (ea), with a



lead-free HASL surface finish.

Figure 64 is the front and back images of the PCB taken from the JLCPCB site.

Standard PCB/PCBA

Advanced PCB/PCBA

SMT-Stencil

3D Printing/CNC

Back to Upload File

Detected 4 layer board of 68.58x66.04mm(2.7x2.6 inches).

Gerber Viewer

Base Material

FR-4

Flex

Aluminum

Copper Core

Rogers

PTFE Teflon

Layers

1

2

4

High Precision PCB

6

8

10

12

14

16

More

Dimensions

66.04

*

68.58

mm

PCB Qty

5

Product Type

Industrial/Consumer electronics

Aerospace

Medical

PCB Specifications

Different Design

1

2

3

4

Delivery Format

Single PCB

Panel by Customer

Panel by JLCPCB

PCB Thickness

0.4

0.6

0.8

1.0

1.2

1.6

2.0

PCB Color

Green

Purple

Red

Yellow

Blue

White

Black

Charge Details

Special Offer

Via Covering

Surface Finish

Build Time

PCB: 3-4 days

3 days

PCBA Only

Calculated Price

Additional charges may apply for special cases

SAVE TO CART

Shipping Estimate

UPS Express Saver

Weight

Coupons

Save £23.82

Save £7.94

Figure 63: PCB Design Production Quote (JLCPCB)

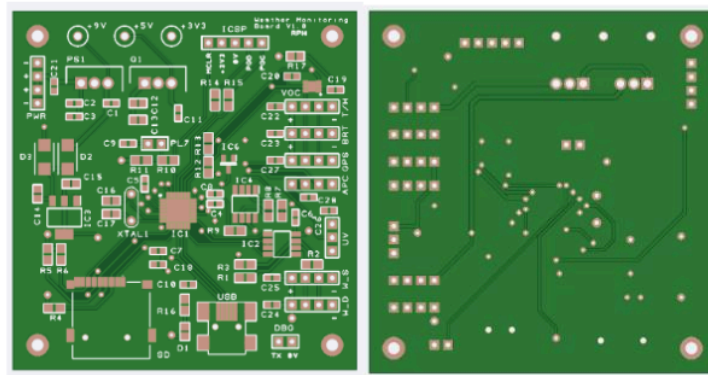


Figure 64: PCB Production Sample Image #1 (Easy-PC)

Future Development

To enable power saving between polling intervals, the PIC could operate at a higher frequency, such as 24MHz - effective instruction frequency of 6MHz (Equation 2), and utilise an IDLE mode. IDLE works when the Enable Bit is set, disabling the CPU core, saving power (to as low as 4% of typical use) whilst leaving the peripherals at full speed [54]. The Recover on Interrupt (ROI) Bit ensures the PIC is able to enable the CPU and program execution when an interrupt is triggered.

FIGURE 4: RELATIONSHIP OF SUPPLY CURRENT AND FREQUENCY IN RUN AND IDLE MODES

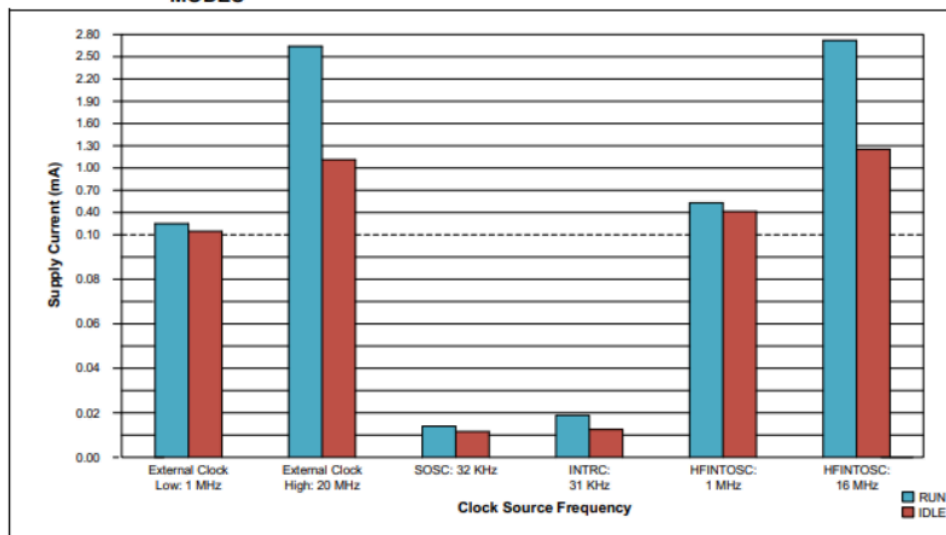


Figure 65: PIC IDLE Mode Power Savings [83]

Logging of greater meteorological data such as the rainfall, rain intensity, and atmospheric pressure would also be beneficial, as well as logging existing data at faster intervals – such as logging wind speed and direction every 100ms to capture gusts [84]. Existing sensors could also be upgraded, for instance; the Brightness sensor (SEN0562) measures up-to 65536 Lux, but 500,000 Lux could be encountered by the system (Direct sunlight intensity at the equator) [26].

The LM-series Linear and LDO voltage regulators (+3V3, +5V, +9V) could be replaced with more efficient/modern alternatives (Switching/DC-DC converter). These are typically 80-90% efficient in comparison to the 30-40% efficiency achieved by the current regulators in the system [85]. This would drastically reduce wasted power and the generation of heat within the system, reducing the battery capacity needed for 14-day operation. An example of a replacement switching regulator would be the TPS56637, which is typically 90% efficient and allows for up to a 28V supply voltage [86].

Finally, a charging circuit for the internal battery could be provided so that disassembly is not required for battery charging (compromising waterproofing) and a waterproofed USB port (PC connection) provisioned on the outside of the case, for the same advantages.

Bill of Materials

Table 28 shows the total cost of the required components to build the system, a total of £846.08, not including cabling, which would add another ~£200.

	FUNCTION	PART NO.	MFR	SUPPLIER	CAT NO.	QTY	UNIT (£)	TOT (£)
PCB ACTIVE	Microcontroller	PIC18F24J50-I/ML	Microchip	Mouser UK	579-PIC18F24J50-I/ML	1	3.05	3.05
	RS485 Transceiver	MAX487CSA+T	Analog Devices	Mouser UK	700-MAX487CSAT	1	4.88	4.88
	9V Voltage Regulator	MC7809CTG	Onsemi	Mouser UK	863-MC7809CTG	1	0.45	0.45
	5V Voltage Regulator	LM7805CT/NOPB	Texas Instruments	Mouser UK	926-LM7805CT/NOPB	1	1.36	1.36
	3V3 Voltage Regulator	LM1117-3.3/NOPB	Texas Instruments	RS UK	533-9577	1	1.55	1.55
	uSD Card Slot	TFP09-2-12B	N/A	Aliexpress	N/A	1	0.58	0.58
	1GB uSD Card	SFSD1024N1AS1TO-E-DF-221-STD	Swissbit	Mouser UK	922-609026	1	25.81	25.81
PCB HEADERS (MALE)	HC-49 16MHz Crystal Oscillator	16.000MHz HC49/4H/30/50/-40+85/18pF/ATF	Euroquartz	RS UK	693-8819	1	0.54	0.54
	USB 2.0 Type C Connector	213716-0001	Molex	RS UK	215-3154	1	1.22	1.22
	5-way 2.54mm Header (PROG)	90120-0765	Molex	RS UK	670-5082	1	1.423	1.423
	4-way 2.54mm Header (PWR)	171971-0004	Molex	RS UK	186-5144	1	1.58	1.58
	4-way 2.54mm Header (RS485)	22-27-2041	Molex	RS UK	483-8483	2	0.049	0.098
	4-way 2.54mm Header (RS232)	22-27-2041	Molex	RS UK	483-8483	1	0.4	0.4
	4-way 2.54mm Header (I2C)	90120-0764	Molex	RS UK	360-6314	3	1.12	3.36
	3-way 2.54mm Header (ANA)	22-27-2031	Molex	RS UK	483-8477	1	0.3	0.3
	2-way 2.54mm Header (MCLR)	90120-0122	Molex	RS UK	670-5029	1	0.47	0.47
	2-way 2.54mm Header (DEBUG)	22-27-2021	Molex	RS UK	483-8461	1	0.251	0.251
	0603 100nF MLCC Capacitor	C0603X104K4RACTU	Kemet	RS UK	205-3267P	20	0.014	0.28

	0603 10uF MLCC Capacitor	C1608X5R1E106M080AC	TDK	RS UK	915-9148	4	0.066	0.264
	0603 1uF MLCC Capacitor	GCM188R71C105KA64D	Murata	RS UK	790-0562	2	0.06	0.12
	0805 22pF MLCC Capacitor	GRM21A5C2E220JW01D	Murata	RS UK	820-2759	2	0.14	0.28
	0805 Red LED	SML-LXF0805SRD-TR	Lumex	Mouser UK	696-LXF0805SRD-TR	1	0.32	0.32
	DO-244A Schottky Diode	VS-10BQ015-M3/5BT	Vishay	RS UK	543-1601	2	0.379	0.758
	0805 10K Resistor	CRCW080510K0FKEA	Vishay	RS UK	679-0816	4	0.032	0.128
	0805 4K7 Resistor	CRCW08054K70FKEA	Vishay	RS UK	679-1496	3	0.02	0.06
	0805 82K Resistor	ERA6ARB823V	Panasonic	RS UK	662-0537	1	0.14	0.14
	0805 1K Resistor	ERJP06F1001V	Panasonic	RS UK	721-7741	1	0.182	0.182
	0805 470R Resistor	ERJT06J471V	Panasonic	RS UK	721-6915	2	0.01	0.02
	0805 120R Resistor	ERA6AEB121V	Panasonic	RS UK	566-840	1	0.125	0.125
	0805 20R Resistor	ERJP06F20R0V	Panasonic	RS UK	721-7615	2	0.022	0.044
	11.1V 30Ah Battery + Charger	12V30AH-3S12P	OmurgA	Amazon UK	N/A	2	132.55	265.1
	XT60 Connector (Male)	180-5361	RS PRO	RS UK	180-5361	2	1.199	2.398
	IP66 Steel Enclosure (Main)	303-91-703	RS PRO	RS UK	775-5300	1	49.92	49.92
	IP66 Polycarbonate Enclosure (UV)	13745501	Spelsburg	RS UK	473-2004	1	9.42	9.42
	10x10mm Quartz Glass Window	FQP-1010	UQG Optics	UQG Optics	N/A	1	9	9
	M2 Standoff (PCB)	244-0411	RS PRO	RS UK	244-0411	4	0.565	2.26
	M2 Machine Screw (PCB)	304-20-086	RS PRO	RS UK	908-7637	4	0.0372	0.1488
	Double-Sided Adhesive Tape	64621-00004-00	Tesa	RS UK	436-2835	1	11.94	11.94
	M3 Nut	303-95-269	RS PRO	RS UK	560-293	24	0.02432	0.58368
	M3 Locking Washer	304-07-015	RS PRO	RS UK	289-657	24	0.0368	0.8832
	M3 Rubber Washer	303-95-229	RS PRO	RS UK	526-350	24	0.03484	0.83616
	M3 Machine Screw	281-007	RS PRO	RS UK	281-007	24	0.3316	7.9584
	VOC Sensor	SGP40-D-R4	Sensirion	RS UK	204-7512	1	3.29	3.29
	Humidity/Temperature Sensor	SEN0385	DFROBOT	Digikey UK	1738-SEN0385-ND	1	15.76	15.76
	Wind Direction Sensor	SEN0482	DFROBOT	Digikey UK	1738-SEN0482-ND	1	35.64	35.64
	Wind Speed Sensor	SEN0483	DFROBOT	Digikey UK	1738-SEN0483-ND	1	35.64	35.64
	Brightness Sensor	SEN0562	DFROBOT	Pi Hut	N/A	1	8.5	8.5
	Analog UV Sensor	ADA1918	Adafruit	Pi Hut	N/A	1	6.5	6.5
	GPS Sensor	ADA4415	Adafruit	Pi Hut	N/A	1	29.4	29.4
	APC Sensor	PMS5003 105770	Plantower	Pi Hut	N/A	1	24.5	24.5
	5-way 2.54mm Connector (PROG)	90156-0145	Molex	RS UK	670-4862	1	0.766	0.766
	4-way 2.54mm Connector (PWR)	50-57-9404	Molex	RS UK	678-3161	1	0.25	0.25
	4-way 2.54mm Connector (RS485)	22/01/3047	Molex	RS UK	679-5388	2	0.196	0.392
	4-way 2.54mm Connector (RS232)	22/01/3047	Molex	RS UK	679-5388	1	0.196	0.196
	4-way 2.54mm Connector (I2C)	90156-0144	Molex	RS UK	360-6134	3	0.641	1.923
	3-way 2.54mm Connector (ANA)	22/01/3037	Molex	RS UK	679-5375	1	0.287	0.287
	2-way 2.54mm Connector (MCLR)	90123-0102	Molex	RS UK	360-5967	1	0.595	0.595

EXTERNAL	Molex C-GRID III Crimp	90119-2109	Molex	RS UK	670-4925	17	0.066	1.122
	Molex SL Crimp	16-02-0086	Molex	RS UK	670-6280	4	0.119	0.476
	Molex KK 254 Crimp	08-52-0123	Molex	RS UK	821-5437	17	0.17	2.89
	2-way 2.54mm Connector (DEBUG)	22/01/2021	Molex	RS UK	679-5287	1	0.151	0.151
	IP68 4-way Panel Connector (Male)	207-2390	RS PRO	RS UK	207-2390	4	15.3	61.2
	IP68 4-way Cable Connector (Female)	304-05-225	RS PRO	RS UK	124-6690	4	26.45	105.8
	IP68 3-way Panel Connector (Male)	207-2386	RS PRO	RS UK	207-2386	2	15.3	30.6
	IP68 3-way Cable Connector (Female)	124-6659	RS PRO	RS UK	124-6659	2	18.23	36.46
	IP68 2-way Panel Connector (Male)	124-6655	RS PRO	RS UK	124-6655	1	9.77	9.77
	IP68 Air Vent	VENT-MS1NMS-O8001	Amphenol	RS UK	231-0184	2	11.74	23.48

Table 28: Bill of Materials (BOM)

Component Datasheets

PIC18F24J50 Microcontroller

<https://ww1.microchip.com/downloads/en/DeviceDoc/39931d.pdf>

MAX487CSA RS485 Transceiver

<https://docs.rs-online.com/7860/0900766b8081322f.pdf>

AD711JRZ Single Supply Operational Amplifier

<https://www.analog.com/media/en/technical-documentation/data-sheets/AD711.pdf>

MC7809CTG +9V Voltage Regulator

<https://docs.rs-online.com/379b/0900766b8170d4fa.pdf>

LM7805CT/NOPB +5V Voltage Regulator

<https://docs.rs-online.com/5192/A700000011214619.pdf>

LM1117-3.3 +3V3 LDO Voltage Regulator

<https://www.ti.com/lit/ds/symlink/lm1117.pdf>

TFP09-2-12B SD Card Socket

https://images.100y.com.tw/pdf_file/10-TFP09-2-12B.pdf

10BQ015 Schottky Diode

<https://docs.rs-online.com/a9a5/0900766b8079100c.pdf>

S-600U 1GB Micro SD Card

https://www.mouser.co.uk/datasheet/2/615/S_600u_fact_sheet-3180318.pdf

3 Pin Bulkhead Connector

<https://docs.rs-online.com/5775/A700000007156902.pdf>

4 Pin Bulkhead Connector

<https://docs.rs-online.com/3a3b/A700000007156934.pdf>

11.1V Lithium Ion 30A Battery Pack

[OmurgA 12V30AH Lithium Ion E-Bike Battery](#)

Main Enclosure

<https://docs.rs-online.com/f3bc/A700000006966815.pdf>

UV Sensor Enclosure

docs.rs-online.com/94e9/0900766b8112f754.pdf

SGP40-D-R4 VOC Sensor

<https://docs.rs-online.com/1956/A700000007055193.pdf>

ADA1918 Analog UV Sensor

<https://cdn-shop.adafruit.com/datasheets/1918guva.pdf>

SEN0562 Ambient Light (Brightness) Sensor

https://wiki.dfrobot.com/SKU_SEN0562_Gravity_I2C_Waterproof_Ambient_Light_Sensor_1_655351x#target_6

PMS5003 Particulate Matter Sensor

https://cdn.shopify.com/s/files/1/0176/3274/files/plantower-pms5003-manual_v2-3.pdf?v=1590607058

SEN0482 RS485 Wind Direction Sensor

https://wiki.dfrobot.com/SKU_SEN0482_RS485_Wind_Direction_Transmitter_V2

SEN0483 RS485 Wind Speed Sensor

https://wiki.dfrobot.com/RS485_Wind_Speed_Transmitter_SKU_SEN0483

*SEN0385 I2C **Humidity**/Temperature Sensor*

https://mm.digikey.com/Volume0/opasdata/d220001/medias/docus/5337/SEN0385_Web.pdf

*SEN0385 I2C Humidity/**Temperature** Sensor*

https://mm.digikey.com/Volume0/opasdata/d220001/medias/docus/5337/SEN0385_Web.pdf

ADA4415 PA1010S I2C GPS Sensor

https://cdn-learn.adafruit.com/assets/assets/000/084/295/original/CD_PA1010D_Datasheet_v.03.pdf?1573833002



Appendix A

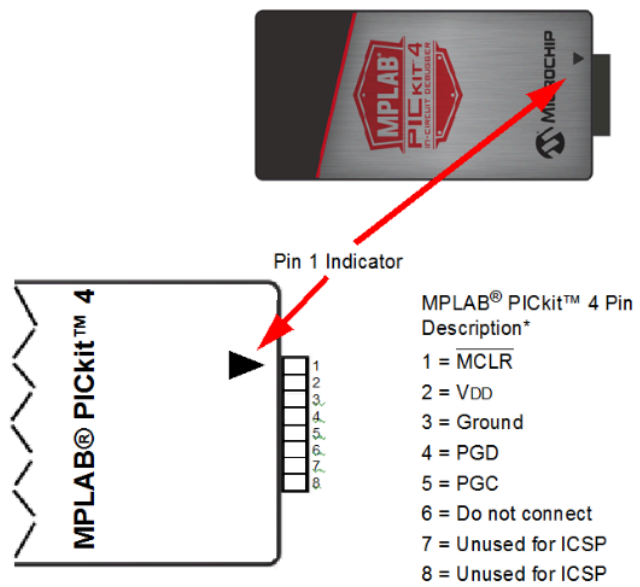


Figure 66: PICKit 4 ICSP Pinout [87]

Appendix B

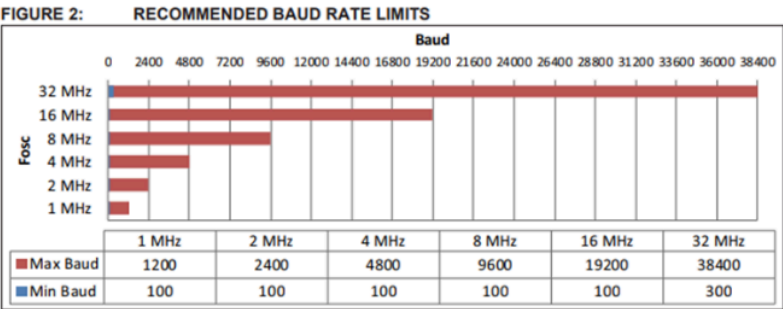


Figure 67: 8-bit PIC Software UART Baud Rate Limits (vs Frequency) [88]

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RPH_ACDA6002EES_ESD2_Assignment

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

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GRADING FORM: SMU GENERIC_GJ

RHYS HIGGINS

77.35

RESEARCH-INFORMED LITERATURE



Good literature review of available systems with a good comparison table of relevant information including a short section of the manufacturers specification . 75%

7.5

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. Your PCB is very good with zero errors. It would have served you better to select the internal oscillator on this design as this could have implemented one of your future enhancements as the Pic can run at

20

up to 48Mhz which is an option with the internal oscillator. 80%

ANALYSIS

 Good selection of microcontroller. Good selection of components well described and selected via the tables.. Reasonable case selection but would have been better served with a more rugged design. Good selection of connectors .75%

26.25

PRACTICAL APPLICATION AND DEP.

 Costings were included in a table without an image but with the manufactures name and part number, supplier's name and part number. Good attempt at future enhancements. 80%

16

SKILLS FOR PROFESSIONAL PRAC.

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

7.6