

David Lewis ESD 2

by David Lewis

Submission date: 30-Jan-2026 10:51PM (UTC+0000)

Submission ID: 274564378

File name: 43143_David_Lewis_David_Lewis_ESD_2_713755_358676585.pdf (908.91K)

Word count: 3443

Character count: 26567



ACDA6002A Electronic Systems Design

Electronic Product Design – Part 2

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1.0 Abstract

This report presents the hardware realisation and implementation of a modular wireless environmental monitoring system, based on the specifications defined in Electronic Product Design – Part 1. The system comprises seven distributed sensor nodes and a central hub designed to monitor indoor and outdoor environmental parameters including air quality and meteorological conditions.

A universal sensor node architecture based on a PIC18F47Q10 microcontroller is proposed, enabling modular deployment through standardised interfaces and reusable schematic blocks. Detailed schematic capture, printed circuit board design, and enclosure integration were undertaken for the sensor node, with design decisions guided by manufacturability, reliability, and cost.

The final design demonstrates a scalable and practical solution suitable for prototype manufacture and long-term environmental monitoring.

2.0 Introduction

This report presents the second stage of the Electronic Product Design project for the ACDA6002A Electronic Systems Design module. Building on the research and system specification established in Electronic Product Design – Part 1, this stage focuses on the practical hardware implementation of the proposed distributed environmental monitoring system.

The system is implemented as a modular wireless sensor network comprising seven sensor nodes and a central hub.

3.0 Task 1 – Schematic Design

3.1 Design Approach

Schematics were developed using Easy-PC following a modular design philosophy. A universal sensor node architecture was adopted to allow multiple node variants to be implemented using a common hardware platform, with different sensing roles achieved through selective population of standardised interfaces.

The schematics focus on hardware connectivity, power distribution, signal integrity, and programming access, reflecting the scope of the assignment.

3.2 Universal Sensor Node Core Schematic

Each sensor node is based on a PIC18F47Q10 microcontroller operating from a regulated 3.3 V supply. Decoupling capacitors are provided at each supply pin, and an ICSP header is included to support in-circuit programming and debugging.

Standardised interface headers provide digital, analogue, and pulse inputs, enabling reuse of the same PCB across all node variants.



3.3 Power Supply Design

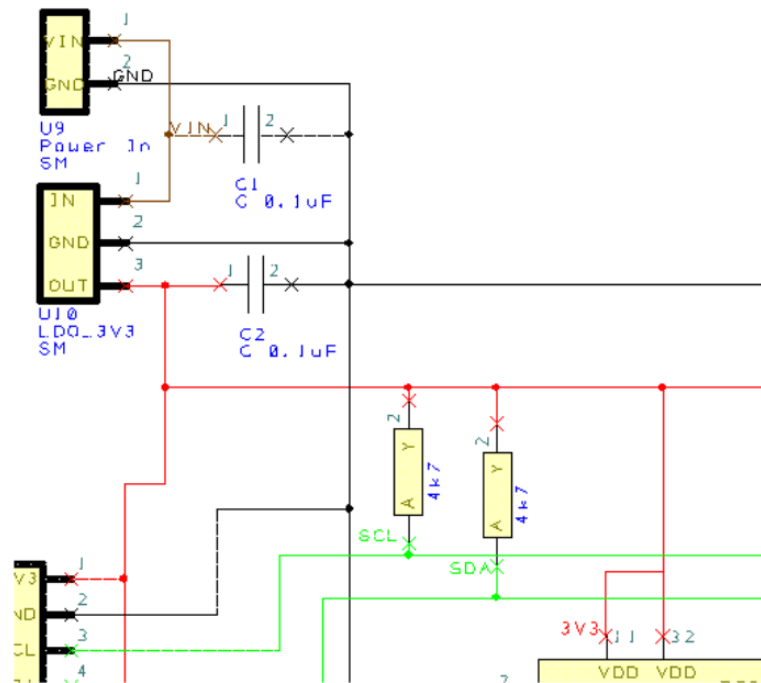


Figure 2 - Power Supply Design

The sensor node is powered from an external 5 V supply, which is regulated to 3.3 V using a low-dropout linear regulator. The regulated 3.3 V rail supplies the microcontroller and all connected sensor interfaces, ensuring compatibility with low-power digital and analogue sensors. Input and output decoupling capacitors are included to improve supply stability and reduce noise.

3.4 Sensor Interfaces

An I²C interface supports environmental sensors such as the BME280/BME680 for sensors. A UART interface is provided for particulate matter sensors such as the SPS30, which are powered from an external 5 V supply. Analogue inputs support electrochemical NO_x sensors via simple conditioning circuitry, while pulse and analogue inputs are used for wind speed and direction sensing.

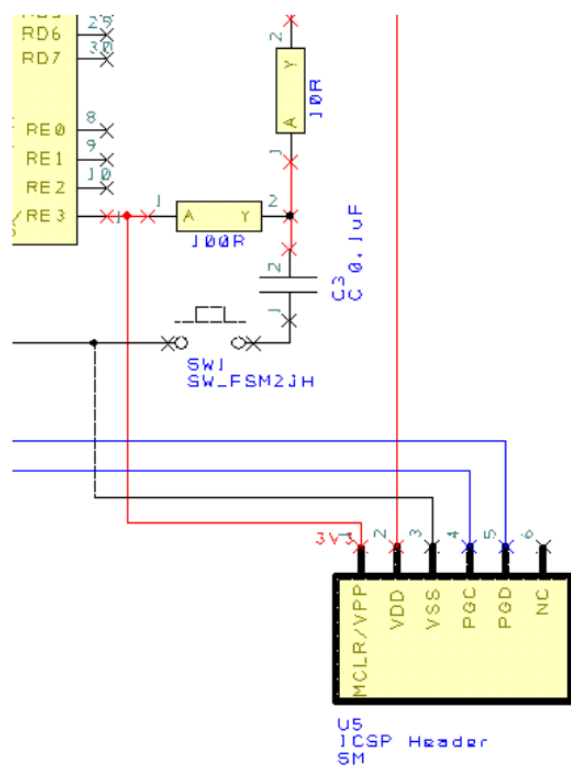


Figure 3 - In-Circuit Programming Support

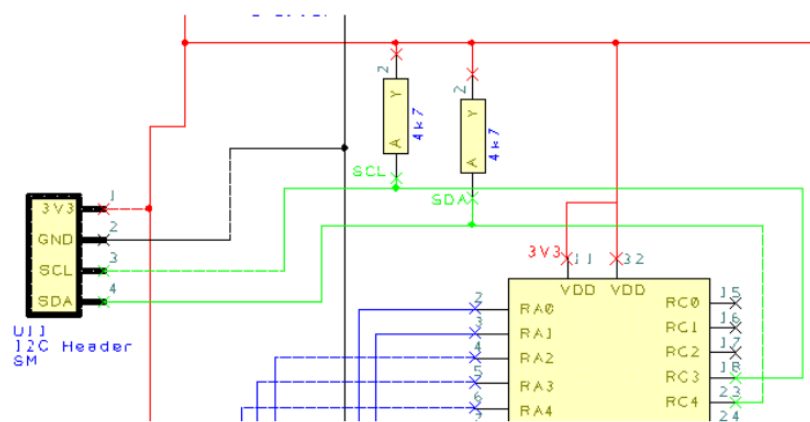


Figure 4 - I2C Header

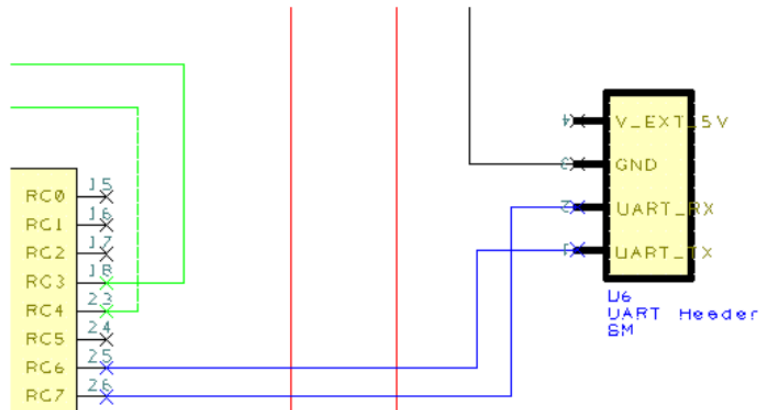
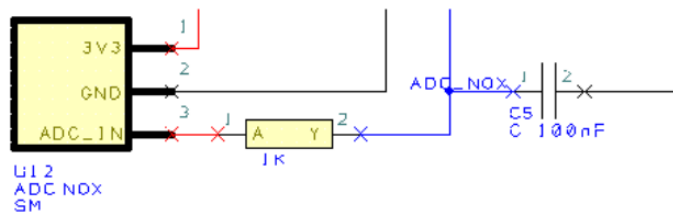


Figure 5 - UART Particulate Matter Interface

3.5 Nox Analogue Sensor Interface

Electrochemical NO_x sensors generate low-level analogue signals proportional to gas concentration. These signals are conditioned using an analogue front-end circuit before being sampled by the microcontroller's analogue-to-digital converter (ADC).

The schematic includes a dedicated analogue input for the NO_x sensor, with simple RC filtering applied to reduce noise and improve measurement stability. This interface is used by both indoor and outdoor NO_x sensor nodes.

Figure 6 - NO_x Analogue Front-End & Interface

3.6 Wind Speed and Direction Interfaces

Wind speed is measured using a mechanical anemometer that produces a pulse output proportional to rotational speed. This signal is connected to a digital input on the microcontroller, allowing pulse counting or timing measurement using internal timers.

Wind direction is measured using a vane sensor with a resistive divider, producing an analogue voltage corresponding to direction. This signal is connected to a separate ADC

input. Together, these interfaces allow the wind node to capture both speed and directional data using simple, robust sensing methods.

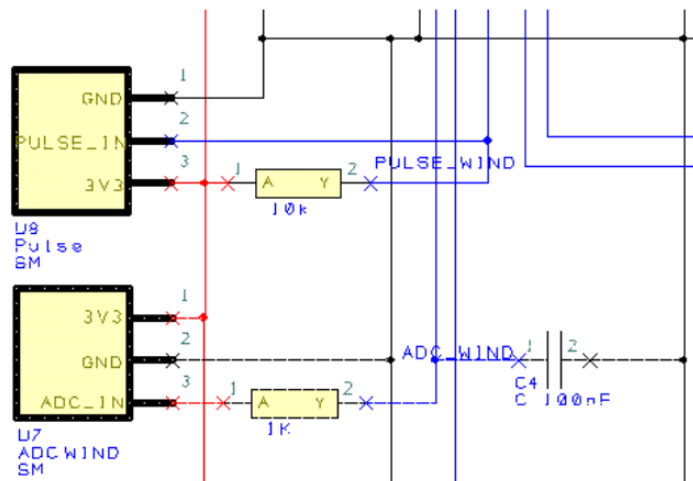


Figure 7 - Wind Speed Pulse & Wind Direction Analogue Interfaces

3.7 RF Communication

Wireless communication is implemented using a generic SPI-connected RF module via a dedicated header. This pluggable approach improves scalability and allows future RF technologies to be adopted without modification to the core PCB.

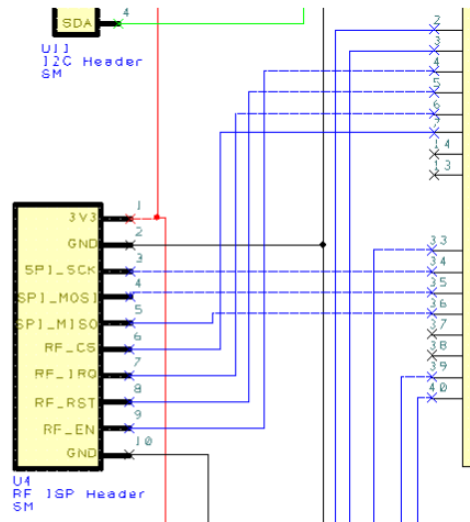


Figure 8 - RF SPI Interface

3.8 Central Hub Hardware Design Scope

Within the scope of this assignment, detailed schematic and PCB development was undertaken for the universal sensor node only. The central hub was addressed at architectural level through system block diagrams and interface definitions. Detailed schematic capture and PCB implementation of the hub would form part of a future development phase.

4.0 Task 2 – PCB Design and Layout

4.1 PCB Design Overview

A two-layer PCB was developed to implement the universal sensor node. The design prioritises modularity, signal integrity, and ease of assembly while maintaining low manufacturing cost.

4.2 PCB Stack-Up and Layer Allocation

The top copper layer is used for signal and power routing, while the bottom layer forms a continuous ground plane to improve signal integrity. The microcontroller is positioned centrally, with connectors placed at board edges to improve accessibility.

Figure 9 below shows the top copper routing, whilst Figure 10 shows the bottom copper layer:

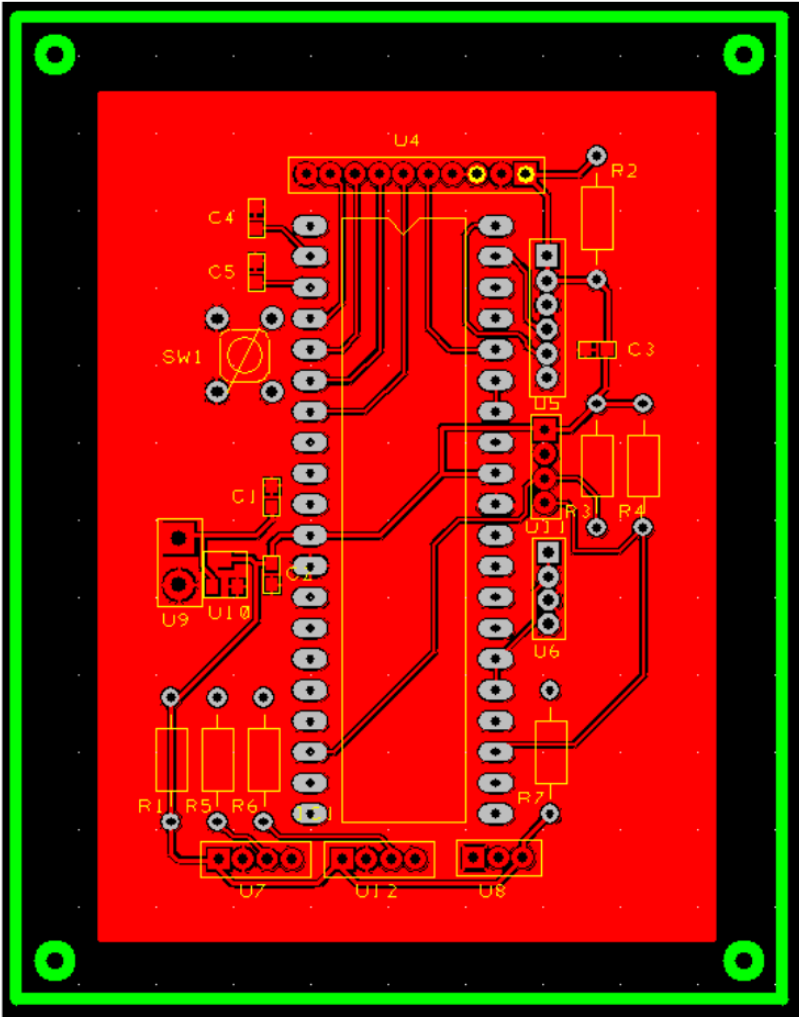


Figure 9 - Top Copper

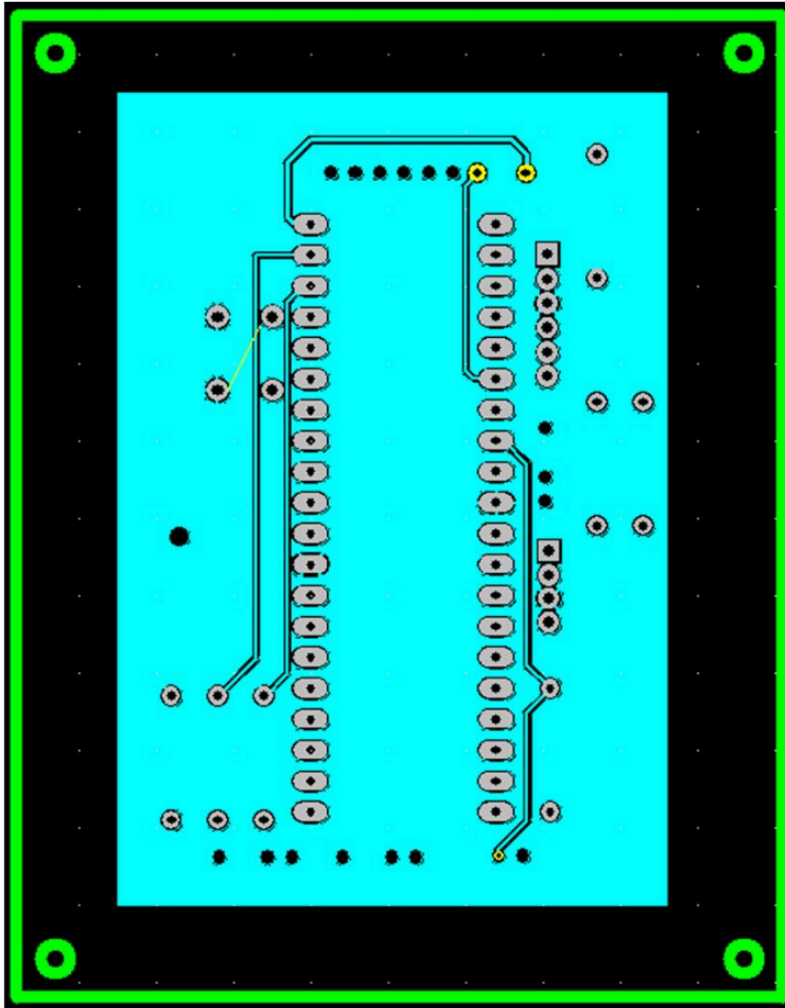


Figure 10 - Bottom Copper Layer

4.3 Component Placement Strategy

Component placement was performed prior to routing in order to minimise track lengths and reduce signal crossover. The PIC microcontroller is positioned centrally on the PCB to provide balanced access to all peripheral interfaces. This reduces routing congestion and simplifies fan-out from the device pins.

External interface connectors are placed around the edges of the PCB to:

- Improve accessibility during testing
- Allow straightforward connection of external sensor modules
- Reduce interference between cables and on-board components

The power regulation circuitry is located close to the microcontroller to minimise voltage drop and supply noise, while decoupling capacitors are placed as close as possible to their associated power pins.

Figure 11 below shows the top silk layer highlighting component placement and reference designators:

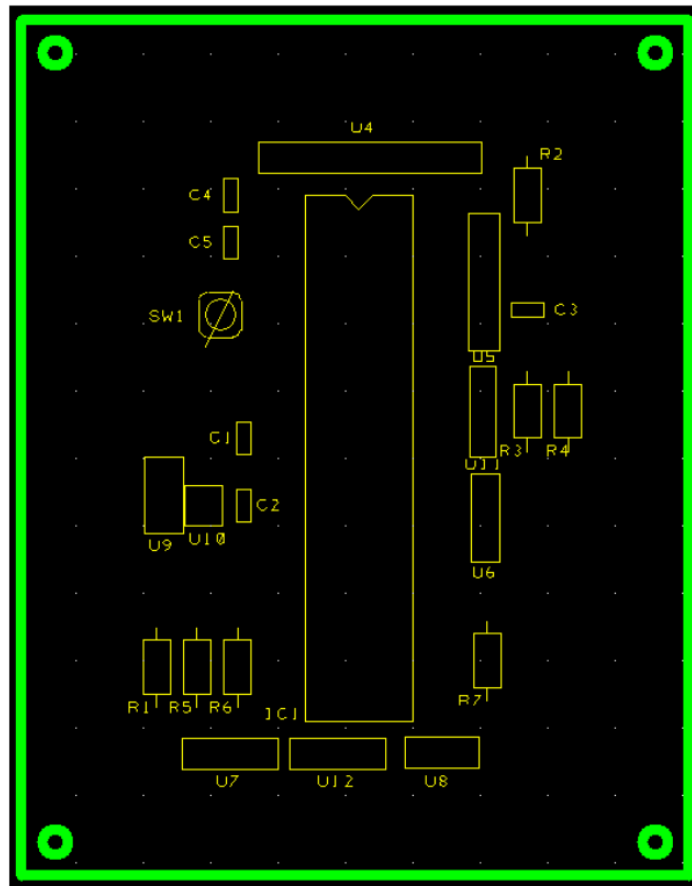


Figure 11 - Top Silk

4.4 Power Distribution and Ground Plane Design

A continuous ground plane is implemented on the bottom copper layer using a copper pour connected to the GND net. This improves signal integrity and noise performance.

Ground connections are made directly through the copper plane rather than routed tracks, which simplifies routing and improves overall PCB robustness.

4.5 Signal Routing and Interface Implementation

Signal routing was carried out on the top copper layer with attention paid to keeping tracks as short and direct as possible. Digital communication interfaces such as I²C, UART, and SPI are routed with minimal length and clear separation from analogue signal paths to reduce noise coupling.

All communication interfaces are exposed via dedicated headers, allowing the PCB to operate as a universal controller for a wide range of external sensors.

4.6 Programming and Debug Support

An ICSP header is included to support in-circuit programming and debugging. The ICSP interface provides access to the required programming signals, including PGC, PGD, MCLR, power, and ground.

The ICSP header is positioned near the edge of the PCB to allow easy access during development and testing.

4.7 Mechanical Considerations

Mounting holes are included at the corners of the PCB to allow secure mechanical fixing within an enclosure or test setup. These holes are electrically isolated from all copper layers to avoid unintended connections and to maintain electrical integrity.

4.8 Design Verification and Validation

Design rule and connectivity checks were performed using Easy-PC, confirming the absence of errors. A 3D visualisation was generated to verify component placement and mechanical practicality.

Figure 12 shows the Easy-PC design check report indicating no errors, while Figure 13 presents a 3D view of the completed universal sensor node PCB.

Design Rule Check Report

Report Written: Friday, January 30, 2026
Design Path: C:\Users\S2219439\Documents\ESD Easy\Easy PC\Node.pcb
Design Title:
Created: 28/01/2026 21:36:32
Last Saved: 30/01/2026 13:00:47
Editing Time: 2295 min
Units: mm (precision 1)

Results

[Gap in Net "GND" between \(405.9,531.2\) and \(408.7,536.6\)](#)
GND.

Number of errors found : 1

Accepted Errors already in the design

No errors found

Figure 12 - Easy-PC Design Check Report

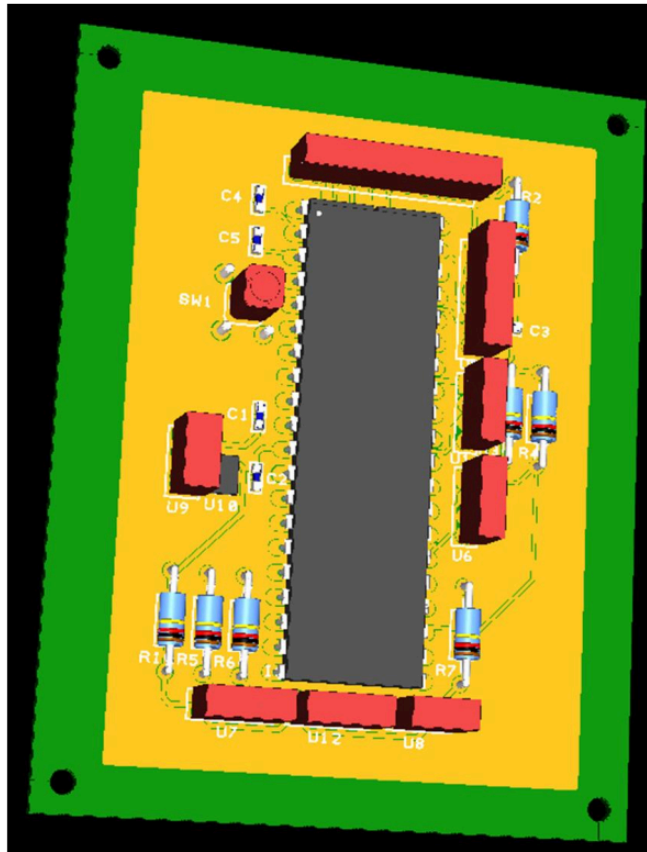


Figure 13 - 3D PCB View

4.9 PCB Design Summary

The completed PCB successfully implements the universal sensor node design specified in Task 1. The use of a two-layer architecture, combined with a dedicated ground plane and modular interface headers, results in a flexible and reusable platform suitable for distributed environmental sensing applications. The PCB layout demonstrates good engineering practice in terms of signal integrity, power distribution, and manufacturability.

5.0 Task 3 – PCB Integration into Enclosures

This task examines how the universal sensor node printed circuit board integrates into suitable enclosures for indoor and outdoor deployment. As discussed in Task 1, detailed PCB and enclosure integration was prioritised for the sensor nodes due to their replication across the system and exposure to varied environmental conditions. The central hub is excluded from this task, as it is a single indoor unit addressed at architectural level only.

5.1 Universal Sensor Node PCB Form Factor

The universal sensor node PCB was designed with enclosure integration in mind from an early stage. The PCB measures approximately 80 mm × 60 mm × 1.6 mm and was selected to fit comfortably within compact off-the-shelf enclosures while allowing sufficient clearance for connectors, mounting hardware, and airflow where required. Four mounting holes are provided at the corners of the PCB, allowing it to be securely fixed to enclosure standoffs using screws. **These holes are electrically isolated from all copper layers to prevent unintended electrical connections and to maintain signal integrity.**



All external connections—including sensor interfaces, power input, and programming access—are provided via board-edge connectors. This arrangement simplifies enclosure cut-outs and allows cables to be routed cleanly without crossing over the PCB surface.

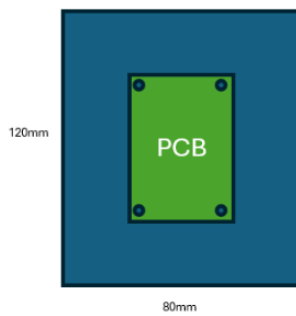
5.2 Indoor Sensor Node Enclosure

Indoor sensor nodes are intended for deployment in controlled environments where exposure to moisture, dust, and temperature extremes is minimal. As a result, a compact ABS plastic enclosure is suitable for indoor use.

A typical indoor enclosure size of approximately 120 mm × 80 mm × 50 mm provides adequate clearance around the PCB and supports ventilation openings without increasing overall enclosure bulk.

The PCB is mounted horizontally within the enclosure using plastic standoffs, ensuring electrical isolation and mechanical stability. Openings in the enclosure are provided for power and sensor cables, with strain relief applied where necessary.

For indoor environmental sensors such as temperature, humidity, and VOC modules, ventilation slots are included in the enclosure to allow ambient air to reach the sensing element. These openings are positioned to minimise the risk of accidental contact while maintaining accurate measurement conditions.



Indoor Sensor Node

- PCB:80x60mm
- Mounting holes: 3mm (corners)
- PCB Mounted on 10mm stand-offs
- Enclosure size: 120x80x50mm
- Vent slots on sides or undersides

Figure 14 - Indoor Sensor Node

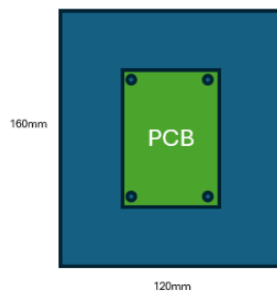
5.3 Outdoor Sensor Node Enclosure

Outdoor sensor nodes are exposed to harsher environmental conditions, including rain, dust, direct sunlight, and temperature variation. Consequently, weather-resistant enclosures with an appropriate ingress protection (IP) rating are required.

A larger enclosure size of approximately 160 mm × 120 mm × 90 mm is used for outdoor nodes to accommodate cable glands, airflow paths, and additional environmental protection features.

The universal PCB is mounted inside an IP-54 rated enclosure using internal standoffs, ensuring that the PCB does not come into contact with enclosure walls. Cable glands are used for all external connections to maintain the enclosure's environmental seal.

Additional features such as radiation shielding, louvred airflow paths, and filtered sensor openings are incorporated to ensure reliable outdoor operation.



Outdoor Sensor Node

- PCB:80x60mm
- Mounting holes: 3mm (corners)
- PCB Mounted on 10mm stand-offs
- IP-Rated enclosure, size: 160x120x90mm
- Larger enclosure for more airflow

Figure 15 - Outdoor Sensor Node

5.4 Sensor-Specific Mechanical Considerations

Different sensor types impose specific enclosure requirements:

Particulate Matter Sensors:

PM sensors require controlled airflow paths to support continuous sampling while preventing environmental ingress.

NO_x Sensors:

Electrochemical NO_x sensors are housed within diffusion chambers that allow gas exchange while shielding the sensor from moisture and direct environmental exposure.

Wind Sensors:

The wind node uses external mechanical sensors mounted on a mast or pole. The PCB is housed separately in a sealed enclosure at the base of the mast, with sensor signals routed via sealed cable entries.

5.5 Access, Maintenance, and Installation

Ease of installation and maintenance was a key design consideration. The enclosure design ensures that:

- The ICSP programming header remains accessible without removing the PCB
- Sensor modules can be replaced without disturbing core electronics
- Cables can be disconnected and reconnected without excessive disassembly

This approach reduces maintenance time and supports long-term system deployment.

5.6 Summary of Task 3

The enclosure integration strategy demonstrates that the universal sensor node PCB can be deployed reliably in both indoor and outdoor environments using appropriate mechanical housings sized to accommodate PCB mounting, airflow, and environmental protection. By combining a standardised PCB with environment-specific enclosure designs, the system achieves flexibility, scalability, and robustness while maintaining accurate environmental sensing.

6.0 Task 4 – Software Design

6.1 Sensor Node Firmware Architecture

The sensor node firmware is designed using a simple modular structure to support reliable data acquisition, wireless transmission, and low-power operation. Following initialisation, the node operates in a periodic measurement cycle, during which sensor data is acquired, packaged, and transmitted to the central hub.

6.2 Sensor Node Operational Flow

Figure 16 illustrates the operational flow of a sensor node. After initialisation, the node periodically wakes, samples connected sensors, transmits a data packet to the central hub, and then returns to a low-power sleep state.

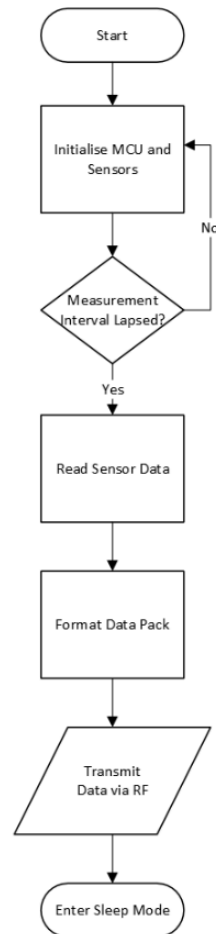


Figure 16 - Sensor Node Flowchart

6.3 Central Hub Firmware Architecture

The central hub firmware is responsible for coordinating communication with multiple sensor nodes, validating received data, and managing long-term storage and user

interaction. Unlike the sensor nodes, the hub operates continuously and is not constrained by low-power requirements.

6.4 Central Hub Operational Flow

As shown in Figure 17, the hub continuously listens for incoming sensor packets. Upon reception, data is validated, time-stamped, stored in non-volatile memory, and optionally displayed locally.

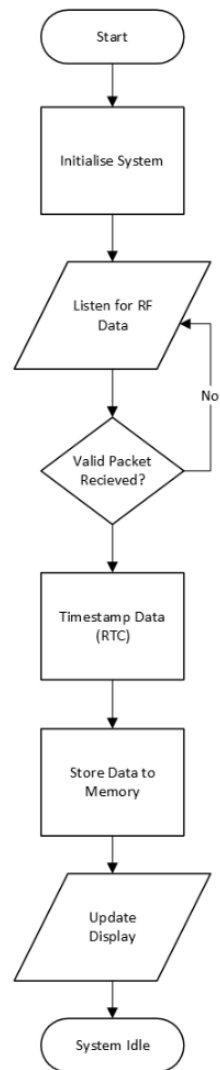


Figure 17 - Central Hub Flowchart

7.0 Task 5 – Costing and Bill of Materials

7.1 Costing approach

Component costs were estimated using typical low-quantity (prototype) pricing and are intended to provide an indicative bill of materials (BOM) for budgeting and feasibility assessment. Costs exclude PCB assembly labour, test time, tooling, and certification, which would be assessed during a later manufacturing phase.

7.2 Universal sensor node BOM (base platform)

Table 1 presents the estimated BOM for one universal sensor node implementing the common PCB, microcontroller, RF interface, regulation, and connectors.

Component	Quantity	Approx. Unit Cost (£)	Total (£)
PIC18F47Q10 MCU	1	4.50	4.50
3.3 V LDO Regulator	1	0.50	0.50
RF Module	1	6.00	6.00
Passive Components (R, C)	~15	0.05	0.75
Pin Headers / Connectors	6	0.30	1.80
PCB (2-layer, small batch)	1	5.00	5.00
Estimated Total			£18.55

Table 1 – Base Universal Sensor Node BOM

7.3 Sensor-specific cost additions

Different node roles can be implemented by adding sensor modules to the universal platform. Table 2 summarises typical sensor add-on costs for key node variants (e.g., environmental sensor, PM sensor, NOx interface, wind sensors). This highlights how modularity supports scalable deployment and allows cost to be matched to monitoring requirements.

Node Variant	Main sensor/module	Add-on cost (£)	Notes
Env (Temp/RH/Pressure/VOC)	BME280/BME680	~8–15	I ² C module
PM node	SPS30 (or similar)	~35–45	UART, higher power
NOx node	electrochemical + AFE	~40–80	depends on sensor + conditioning
Wind node	anemometer + vane	~25–60	pulses + analogue divider

Table 2 - Sensor Add-ons

7.4 Estimated system cost

Based on the required deployment of seven nodes, the approximate prototype BOM cost can be estimated by multiplying the base node cost by the number of nodes and adding the sensor-specific costs per node type. This approach provides a clear, scalable method for early-stage system budgeting.

8.0 Task 6 – Risks, Limitations and Future Improvements

8.1 Identified Risks and Mitigation

Risk	Impact	Mitigation
Sensor drift over time	Reduced data accuracy	Periodic calibration and sensor replacement
Wireless interference	Packet loss	Packet validation and retransmission strategy
Outdoor environmental exposure	Hardware damage	IP-rated enclosures and cable glands
Power instability (nodes)	Data gaps	Battery monitoring and low-power design
Scalability limits	Reduced performance	Modular addressing and hub storage margin

Table 3 - Risk Table

8.2 System Limitations

The system is intended for low- to medium-density environmental monitoring and is not optimised for high-speed or safety-critical applications. Wireless communication range and reliability are dependent on the deployment environment, and sensor accuracy is limited by the characteristics of low-cost commercial sensors.

8.3 Future Improvements

- Encryption and authentication of wireless data
- Adaptive sampling rates based on environmental conditions
- Cloud connectivity for remote access and analysis
- Automated calibration tracking
- Detailed PCB and enclosure development for the central hub

9.0 Conclusion

This assignment presented the design of a distributed environmental monitoring system, focusing on the development of a universal sensor node suitable for deployment in both indoor and outdoor environments. Detailed schematic capture, printed circuit board design, and enclosure integration were undertaken for the sensor node, reflecting its critical role as the most replicated and deployment-sensitive element of the system.

A modular hardware and software architecture was adopted to support scalability, maintainability, and flexibility, enabling different sensor types to be implemented using a common platform. Design decisions were guided by practical considerations including power consumption, manufacturability, environmental protection, and cost, with indicative bill of materials estimates demonstrating the feasibility of the proposed system.

While the central hub was addressed at architectural level only within the scope of this assignment, its role in coordinating wireless communication, data handling, and user interaction was clearly defined. Future development work would include detailed schematic

and PCB implementation of the central hub, alongside further refinement of firmware, calibration strategies, and system-level testing.

10.0 References

- [1] Akyildiz, I.F. et al. (2002) Wireless sensor networks: a survey. *Computer Networks*, 38(4), pp.393–422.
- [2] Bosch Sensortec (2023) BME680 Environmental Sensor Datasheet.
- [3] Sensirion (2022) SPS30 Particulate Matter Sensor Datasheet.
- [4] Microchip Technology Inc. (2023) PIC18F47Q10 Datasheet.
- [5] IPC (2017) IPC-2221: Generic Standard on Printed Board Design.
- [6] World Health Organization (2021) Global Air Quality Guidelines.

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Comment 1

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Comment 2

Why not connect them to ground? That way if your enclosure is metallic, it will act as extra shielding.

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GRADING FORM: SMU GENERIC_SMOSEY

DAVID LEWIS

74.50

ENGAGEMENT WITH LITERATURE

including reading, referencing, academic conventions and academic honesty



There are no marks available for this section

0

KNOWLEDGE & UNDERSTANDING

Knowledge of the basic underlying concepts and principles of a subject.



Good PCB designs, although it is unclear what the "external 5V supply" is and where it is in the general arrangement of the nodes. Good explanation of the software structure for both the nodes and the hub. Some of the diagrams could have been clearer - e.g. the schematics.

6

COGNITIVE & INTELLECTUAL

Evaluate underlying concepts and principles of a subject and interpret qualitative and quantitative data in order to develop lines of argument and make sound judgements.

-  Your design is a viable design and could operate in alignment with the specifications given.

24

PRACTICAL APPLICATION SKILLS

Different approaches to solving problems in particular contexts.

-  Your costing could have more detail in it. You have grouped components together and provided an estimated cost when they could have been itemised individually. Some of the costs seem either rounded off or estimated. Overall a high quality design with most aspects thought about.

37.5

TRANSFERABLE SKILLS

Communicate the results of their study/work accurately and reliably, and with structured and coherent arguments; the qualities needed for employment requiring the exercise of some personal responsibility within a structured and managed environment.

-  Can communicate professionally confidently and consistently in a suitable format. Work is coherent, very fluent and is presented professionally. Demonstrates excellent graduate employment skills and an appetite for further development.

7