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Electronics System Design –
ACDA6002A

Electronic Product Design – Part 2

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Abstract

The aim was to design, develop, and implement a distributed wireless air-quality monitoring system intended to provide continuous oversight of environmental conditions at a materials production site. The system employs multiple sensor nodes, each equipped with a PIC16F18855 microcontroller, a selection of sensors, communication modules, and power sources. Each node can monitor critical air-quality parameters including air pressure, temperature, humidity, volatile organic compounds (VOCs), particulate matter (PM10 and PM2.5), and nitrogen oxides (NOx), with outdoor nodes additionally measuring wind speed and wind direction. Sensor nodes will transmit their data wirelessly to a central hub, which stores at least 30 days of readings, and provides real-time visualisation through an integrated display. The modular design of both nodes and the hub allow for scalable deployment, enabling nodes to be added, replaced, or removed without major redesign or disruption of the system. The project prioritises energy efficiency, and robustness to environmental factors, ensuring long-term operation with minimal maintenance. By providing accurate, high-resolution environmental data, the system supports compliance with air-quality regulations, facilitates early detection of pollutants, and enables timely corrective actions to mitigate environmental impacts.

1. Introduction

Air-quality monitoring has become critical in industrial and urban environments, where pollutants such as particulate matter, volatile organic compounds, and nitrogen oxides pose significant health, environmental, and regulatory risks. Traditional air-quality monitoring systems often rely on single-point measurements, which fail to capture spatial and temporal variations across complex sites. These systems may also require extensive wiring, which can complicate installation and increase costs. To address these limitations, distributed sensor networks (DSNs) provide a robust solution by enabling simultaneous measurements at multiple locations with wireless communication to a central hub.

In this project, a distributed air-quality monitoring system was designed to provide continuous, real-time measurement across both indoor and outdoor areas of a materials production facility. The system consists of sensor nodes connected wirelessly to a central hub. Each node incorporates a PIC16F18855 microcontroller, chosen for its ultra-low power consumption, integrated analogue and digital peripherals, and compact form factor, which allows for reliable data acquisition and processing while minimising energy use. Sensors are selected based on their sensitivity, response time, environmental resilience, and suitability for wireless operation. Wireless communication ensures that data from multiple nodes can be collected efficiently, while the central hub stores and visualises readings for operational decision-making. The flexibility of the design allows rapid adaptation to changing monitoring requirements, including the addition of new sensors or relocation of nodes.

2. Task 1 – System Schematic Design



The first stage of the design process involved translating functional block diagrams into detailed schematic diagrams. Each sensor node was designed to integrate power supplies, a microcontroller, multiple environmental sensors, signal conditioning circuits, and wireless communication modules. The PIC16F18855 microcontroller serves as the core of each node, providing the necessary interfaces for sensor communication, data acquisition, and wireless transmission. Its integrated ADC channels, USART, SPI, and I2C interfaces simplify the connection of multiple sensors, while its ultra-low power features extend battery life, particularly in outdoor nodes powered by renewable sources such as solar panels.

The BME680 sensor, capable of measuring temperature, humidity, air pressure, and VOC levels, communicates with the microcontroller via I2C. Its inclusion reduces the number of separate sensors required per node, streamlining both physical layout and data management. The SPS30 sensor measures particulate matter levels, including PM10 and PM2.5, and is particularly suited for outdoor deployments due to its robust construction and rapid sampling capabilities. The Alphasense NO-B4 sensor measures nitrogen oxides, producing an analogue signal that requires

amplification and filtering through a dedicated signal conditioning stage. For outdoor nodes, the Gill WindSonic measures wind speed and direction using ultrasonic sensing, providing additional environmental context for pollutant dispersion.

Signal conditioning is particularly critical for the NO-B4 sensor. Low-level analogue signals are prone to noise interference, necessitating the use of operational amplifiers, filters, and precise passive components to ensure measurement accuracy. Careful separation of analogue and digital circuitry on the schematic must be maintained to reduce crosstalk and interference from the microcontroller or RF module. The RF module interfaces with the PIC16F18855 via a USART serial connection, allowing reliable wireless transmission to the central hub. Power regulation circuits ensure stable voltages for all components, and decoupling capacitors mitigate switching noise.

The central hub schematic will integrate a higher-capability processing unit capable of storing at least 30 days of continuous data. It will feature wireless receivers compatible with the RFM210LCF modules, an OLED display for real-time visualisation, and user input buttons to allow interaction and configuration. Power supplies must be scaled to accommodate continuous operation, and the design will include sufficient protection features to ensure long-term reliability.

3. Task 2 – PCB Design

PCB design will be conducted using Easy-PC, following a two-layer approach to balance manufacturability, cost, and performance. The top layer will primarily host component placement and signal routing, while the bottom layer will serve as a ground plane with additional signal routes where necessary. This arrangement minimises electromagnetic interference, supports compact designs, and improves signal integrity for sensitive analogue measurements.

Component placement will be guided by electrical relationships and functional grouping. Analog components, including the NO-B4 conditioning circuitry, will be physically separated from digital components to reduce interference. Sensors requiring exposure to the environment, such as the BME680 and SPS30, will be placed near PCB edges to allow direct contact with air while maintaining protection from dust and moisture. The RF module and its antenna will be strategically positioned to minimise obstructions and maximise signal propagation.

Trace widths must be calculated according to expected current loads, adhering to IPC-2152 recommendations, and spacing must follow fabrication standards to prevent shorts and crosstalk. Power traces will be widened to minimise voltage drop, while signal traces follow the shortest possible routes with minimal vias. A single star-ground configuration will be implemented to avoid ground loops, and analogue and digital grounds carefully separated.

To enable firmware programming and debugging, each PCB must include an ICSP header conforming to PIC microcontroller pinout standards. Connectors for external modules and antennas will be placed along the PCB edges with sufficient spacing for easy insertion and removal. Mounting holes aligned with the selected enclosure will allow secure mechanical fixation, and openings or vents will be incorporated for sensor exposure.

The PCB dimensions will be minimised to fit within ASA-PC enclosures while accommodating all required components. Each design will balance compactness with accessibility, ensuring both manufacturability and serviceability.

4. Task 3 – Enclosure Integration

The mechanical design of sensor nodes will be guided by durability, environmental protection, and serviceability requirements. ASA-PC was chosen as the enclosure material due to its high impact resistance, UV stability, and resistance to extreme temperatures and chemical exposure. Each enclosure will be designed to accommodate the PCB securely using screws or plastic clips, ensuring stability even under mechanical shock or vibration. Sensor exposure openings will be carefully positioned to allow accurate environmental measurement while preventing ingress of dust, water, or other contaminants.



Antenna connectors will be located near the edges to optimise wireless communication, while battery compartments will be designed for easy replacement or connection to a solar charging system. Enclosure design will also consider airflow for passive cooling and modularity for future upgrades, ensuring that sensors, batteries, and electronics can be serviced or replaced without disassembling the entire system. Minimising overall dimensions while maintaining sufficient spacing for internal components will be prioritised, thereby reducing material usage and installation footprint without compromising safety or performance.

5. Task 4 – Software Functions and Design

The software design for the distributed sensor network will be structured around modularity and reliability. Each sensor node will run firmware on the PIC16F18855 microcontroller that controls sensor data acquisition, signal conditioning, and wireless communication. The firmware will be designed to operate in a low-power mode, periodically waking the microcontroller to read sensors, process data, and transmit readings to the central hub. Sensors with slow-changing parameters, such as temperature, humidity, and VOC levels, will be sampled every five minutes to reduce power consumption and extend battery life. Faster-changing parameters, such as particulate matter from the SPS30 sensor and wind measurements from the WindSonic, will be sampled more frequently—every five seconds and every second, respectively—to capture

transient environmental changes. Nitrogen oxide levels will be sampled every ten seconds to balance temporal resolution with memory and energy constraints.

Data will be formatted into structured packets for wireless transmission via the RF module, which implements error detection and retransmission to improve communication reliability. At the central hub, incoming data is to be stored in non-volatile memory capable of holding at least 30 days of readings. The software running on the hub will handle real-time data visualisation on the Winstar OLED display, configurable threshold alarms, and logging for long-term analysis. Structure diagrams and flowcharts will be used to guide software development, ensuring modularity, ease of debugging, and scalability. This software architecture also allows future integration of additional sensors or communication protocols, such as LoRaWAN or Wi-Fi, without requiring significant redesign.

6. Task 5 – Costing Analysis

6.1 Sensor Node Cost Breakdown (Approximate)

Item	Estimated Unit Cost (£)
PIC16F18855 MCU	1.50
BME680 Sensor	10.00
SPS30 Sensor,	40.00
NO-B4 Sensor,	15.00
RFM210LCF RF Module	5.00
LiPo Battery	8.00
PCB & Assembly,	12.00
Enclosure,	10.00
Miscellaneous (connectors, passives)	5.00
Total per node	~106.50

6.2 Central Hub Costs

Includes higher specification MCU or embedded board, display, memory, power supply, and enclosure. Estimated around £150–200 depending on chosen components.

6.3 Comments

Each sensor node was estimated to cost approximately £106.50, including the microcontroller, sensors, RF module, battery, PCB, enclosure, and miscellaneous components. The central hub, incorporating additional processing capability, memory, and user interface elements, was estimated to cost between £150 and £200. These costs reflect a compromise between

performance, energy efficiency, and affordability suitable for medium-scale industrial deployment.

7. Task 6 – Design Specification Compliance

The completed distributed air-quality monitoring system will successfully meet all of the specifications established during the initial project planning. Each sensor node will be capable of continuously measuring multiple environmental parameters, including air pressure, temperature, humidity, volatile organic compounds (VOCs), and particulate matter concentrations (PM10 and PM2.5). In outdoor deployments, additional measurements such as wind speed and wind direction will be captured, providing a comprehensive environmental profile. The system's modular design will ensure that individual nodes can be added, removed, or upgraded without disrupting overall network functionality, allowing the monitoring infrastructure to adapt to changing requirements or expanded coverage areas. The use of ultra-low-power PIC16F18855 microcontrollers and carefully selected power sources, including rechargeable LiPo batteries and optional solar input, will ensure that the nodes operate efficiently over extended periods with minimal maintenance. Wireless communication to a central hub is reliable and allows for the aggregation, storage, and visualisation of up to 30 days of continuous data. The central hub will provide live monitoring capabilities, configurable alert thresholds, and a user-friendly interface. Additionally, careful attention to PCB layout, component placement, and enclosure design guarantees manufacturability, serviceability, and robustness against environmental factors such as temperature extremes, moisture, and mechanical stress. Overall, the system will meet the project's functional, operational, and environmental specifications.

8. Task 7 – Suggested Improvements and Future Work

While the current system meets its design specifications, several improvements could be implemented in future iterations to enhance performance, reliability, and usability. Firstly, incorporating higher-capacity or energy-harvesting power sources, such as integrated solar panels with battery management, would increase node autonomy and reduce maintenance intervals. Secondly, implementing redundancy in the wireless communication network, such as mesh networking protocols, would improve data reliability in larger deployments or in environments with potential RF interference. Thirdly, future versions could integrate additional environmental sensors, including CO₂, ozone, or methane, to expand monitoring capabilities and provide a more comprehensive environmental profile.

Improved software functionality could also enhance the system. For example, implementing local data analysis and anomaly detection on the sensor nodes would allow alerts to be triggered even if the central hub is temporarily unreachable. Advanced visualisation tools and remote access via web or mobile interfaces could further increase operational flexibility. Additionally,

PCB layout improvements, such as separating high-speed digital traces from analogue signals more effectively or adding additional shielding, could enhance signal integrity. These improvements would support the long-term adaptability, resilience, and scalability of the monitoring system, ensuring that it remains relevant and effective in evolving environmental monitoring applications.

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PAGE 1

PAGE 2

PAGE 3



Comment 1

You have not included ANY diagrams in this report. Where is the design?



Comment 2

Where are these diagrams?

PAGE 4

PAGE 5



Comment 3

You should have included a diagram here to show the general arrangement of each node and the main hub.

PAGE 6



Comment 4

Why are you using estimated costs and not actual costs from suppliers?



Comment 5

You should have presented a design for this which would show all your chosen components.

PAGE 7

PAGE 8

GRADING FORM: SMU GENERIC_SMOSEY

JADE WILLIAMS

36.50

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.



While you have spoken about the hardware design, you have not presented any evidence of this as diagrams. You were supposed to include schematic diagrams and images of the PCB layers. You have not done this and as a result I cannot give the marks I know you are capable of.

3

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.



Again, while you have written about how the design complies to the original specification, you have not evidenced this with the actual design. As a result I cannot give the marks I know you are capable of.

9

PRACTICAL APPLICATION SKILLS

Different approaches to solving problems in particular contexts.



You have chosen good technologies, but without seeing the actual design this is difficult to mark. Your costing is not accurate as you have used estimated costs and not broken down the cost to include passive components, PCB mounting hardware, connectors, antennae etc.

17.5

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, but lacks detail in all sections as reflected by the marks in the other sections.

7

