Gas Monitor for Animal Farms

Tanmay Sarkar, Matthew Owen, Joaquin Salas,
Blake Schwartzkopf

MIDTERM REPORT

Table of Contents

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Concept of Operations

Concept of Operations
for
Gas Monitor for Animal Farms

Team 28

Approved by:

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Project Leader Date

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T/A Date

Change Record

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-				Draft Release

Table of Contents

List of Figures

1. Executive Summary

Being able to provide live data for the living conditions of animals inside farms gives key insight into animals long term health. The purpose of the project is to design a fixed and durable, gas-monitoring device that can track and store data about the amount and types of gas that are present. The full list of gases that the system will track includes ammonia, carbon dioxide, methane, nitrous oxide, and hydrogen sulfide. The system will be as miniaturized as possible, while also prioritizing performance details such as power efficiency, signal processing, and data management. Our design must be able to function efficiently regardless of potential environmental challenges that may occur. The gas monitor will utilize wireless communication to transmit the readings to a database, where it will be stored and visualized. This will not only keep track of the live conditions inside the farm, but will allow the user to track the abundance of certain gases over a long period of time. The ultimate goal of the collected data is to correlate gas concentrations with animal health outcomes. This could provide valuable insights for potential improvements in farm conditions, improved quality of animal meat, and minimized cost of veterinary expenses.

2. Introduction

This Concept of Operations report will provide essential context to the gas monitoring in animal farms. The health of the animals inside a farm is one of the most important aspects of upholding the sustainability of farms in the long term. We are attempting to analyze the gases present in the animals' living spaces, which will allow clients/researchers to improve the long-term health of the animals. The more overlying objective of the system is to be able to provide live monitoring of various gases inside an animal farm. This data will be outputted and stored in a central database, where it can be viewed and analyzed. We hope to be able to make our system completely seamless and easy to use in a flexible manner.

2.1. Background

There are integrated gas sensing systems in place at certain farms, which often come with data-logging features. We commonly see fixed gas sensors that continuously measure specific gases. The point of these systems is to set off an alert if a certain gas exceeds an expected amount. While our system could be used in this manner, the primary purpose is to be able to find long term health impacts of different gases on animals. By being focused on data management and tracking over time, we can improve the conditions in which these animals are living. We plan on building a fixed gas monitor that can handle tracking multiple gases simultaneously. Having one system will benefit the user by allowing the data to be handled easily and actions can be taken while using one seamless system.

2.2. Overview

Figure 1: Concept picture of fixed sensing device

As shown above, the system will be a fixed device that will be placed in industrial animal farms. It will use sensors on a PCB, placed inside a firm housing system, and gather gas concentration data over a period of time. The microcontroller inside the system will use either LoRaWAN, Zigbee, or Bluetooth to transmit data. The data will then be stored inside a central database in a .JSON format, so that it is easy to work with. Each subsystem of the project will be powered from an electrical outlet. The system will be housed in a durable device, made to withstand multiple environmental elements. Finally, it will be visualized in a UI using a web application.

2.3. Referenced Documents and Standards

- Environmental Protection Agency (EPA) Regulations
- Wireless Communication Regulations (FCC)
    - FCC Part 15: Devices should not interfere with licensed communication devices and must meet low-power standards
    - EMI Compliance: Ensure that the device does not generate harmful EMI that could impact other devices.
- .JSON Standard - RFC 8259 (Microcontroller output)
- IEEE 802.11 Wireless Communications Standards
- LoRa Alliance Website - LoRaWAN Specifications
- MEMS Gas Sensors - A Review
- IEEE 2700 Standard for Sensor Performance Parameter Definitions

3. Operating Concept

3.1. Scope

The project involves the development of a durable, miniaturized environmental sensor that monitors key elements (e.g., ammonia, carbon dioxide, methane, etc.) in agricultural environments. The device will wirelessly transmit data to a central server for future analysis, enabling farmers and researchers to explore connections between gas concentrations and the wellbeing of livestock. The project goal is to create a prototype that operates with minimal power consumption while maintaining high accuracy and reliability.

3.2. Operational Description and Constraints

The environmental sensor will be deployed in agricultural fields to continuously monitor gases. Data will be collected from the sensors and transmitted wirelessly to a centralized server, where the user can access historical gas readings. The sensor must be durable enough to withstand harsh environmental conditions such as extreme temperatures, humidity, foreign objects, and physical impacts. Constraints include optimizing the design to ensure minimal power consumption and maintaining reliable communication despite interference or range limitations. The system must also be able to withstand extreme conditions while appearing sleek and innovative.

3.3. System Description

The Livestock Gas Monitoring System is designed with four key subsystems, each contributing to the detection, transmission, and collection of gas concentrations produced in animal farming environments.

1. Sensors and Signal Conditioning

The system will utilize a series of high-precision sensors connected to the Gas Monitoring System to measure the concentration of common gases emitted by livestock waste and fertilizers. The list gases include ammonia (NH_3), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and hydrogen sulfide (H_2S).

- Signal Conditioning Circuits will amplify and filter the raw signals from the sensors, converting them into digital data. This will ensure that the gas concentration readings are precise, with minimal noise and distortion, before being processed by the microcontroller.

2. Power Distribution and Housing Unit

The system will require an intricate and precise power supply circuitry that converts AC power from an outlet to DC power for various components. It will involve designing a PCB to meet all the power needs of all other subsystems in the project.

Power will be needed for the sensor circuitry, a microcontroller, PCB's, etc. Additionally this subsystem will also have the task of designing a housing unit that will compact, sleek, and provide protection for sensors, PCBs, and the microcontroller.

- The PCB designed in this subsystem will first take the AC power from a wall outlet and implement rectifiers to convert it to DC. Once this voltage has reached the PCB, it will be manipulated to reduce noise in the voltage. A buck-boost converter will then adjust the voltage level according to the specific needs of the rest of the subsystem. Lastly, all power will be routed and delivered to all other parts of the gas monitoring system..
- Development of a compact and most importantly extremely durable housing unit. This housing will serve the purpose of protecting the different sensors, PCB's, circuitry, and the microcontroller. Durability is one of the most important aspects of this design as it must be built to design and withstand harsh environmental conditions. It must stand firm against bumps, drops, and any other possible damages.

3. Microcontroller and Data Transmission

The system will be controlled by a microcontroller that manages data collection from several sensors, processes the signal data, and transmits the data to a centralized server. This subsystem includes:

- Data Formatting and Preprocessing: The microcontroller will apply necessary calibration algorithms from several sensors the device will have to prepare for transmission.
- Wireless Communication Module: The data will be transmitted wirelessly using a suitable communication protocol such as LoRaWAN, Zigbee, or Bluetooth. These protocols will be compared based on their reliability, long-range capabilities, and low power consumption.
- Data Rate Control: The user will be able to manually adjust the rate of data transmission. Data rate is important to control due to factors such as network conditions.

4. Data Management and Web Application

The system will interface with a web-based application that will take in the data from the microcontroller, visualize it, and provide the user with an interface that can easily be used. The aim is to have the data outputted in a .JSON format, so that it can be easily handled in the post-measuring phase. Ultimately, after receiving the data from the microcontroller, the web application will provide the user with:

- Real-Time Data Visualization: Users will have access to real-time data on gas concentrations, displayed in dashboards with visual aids.

- Data Storage and Historical Analysis: One major objective of the system is to allow users to track long-term data. We will store the data for a long period of time so the user can utilize this feature to see trends in the gas content of the area.
- AI and Machine Learning for Data Analysis: One long-term goal of the system that could be included in the future is a predictive algorithm that will leverage past trends of gas content in order to predict what the gas abundance might look like in the future. This can be used to preserve the health of the animals ahead of time. This would require a certain amount of data already measured inside a farm, which can be used to train the algorithm.

3.4. Modes of Operations

The Gas Monitoring System will have a single mode of operation which is active monitoring mode (automatic). The system will continuously collect data from various gas sensors found within the monitor. As data is being collected (every 5-30 seconds) it will then transmit to a central server, where readings will be stored and visualized in a user-friendly interface. The device will include a display to show an indicator that the device is transmitting.

3.5. Users

The gas monitoring system will be marketed for farmers and industrial livestock production facilities, it will provide users the ability to monitor the gas emissions in farms. The ability to monitor gases found in livestock farms and access historical data will enable researchers and farmers to gain a deeper understanding of their production environments and make data-driven decisions to improve quality of meat, decrease amount spent on veterinary expenses, and enhance sustainability.

3.6. Support

Support for the gas monitoring system will be provided as a user operators manual providing detailed instructions on installation, maintenance, and sensor calibration guides. The manual will also include instructions on how the user can interact with the web based interface and add/drop monitors to the system. The system as a whole will be designed to be both intuitive and user friendly to ensure it maintains the ability to be easily used and implemented.

4. Scenario(s)

4.1. Livestock Health and Environment monitoring

The main use case for the Gas Monitoring System is to improve the health of livestock by monitoring the air quality in animal housing areas such as barns. These housing areas will be monitored for harmful gases that often show up here. Gases like ammonia can negatively impact animal health by impacting respiratory health. By using the Gas Monitoring System, farmers can swiftly identify the potentially harmful conditions in the housing areas and address the conditions immediately. This use case will help to promote healthier livestock that is more productive.

5. Analysis

5.1. *Summary of Proposed Improvements*

- The user will be able to control rates of data transmission.
- The system will interface directly with a web-based application that will implement predictive algorithms to forecast future gas concentrations.
- All proposed components will be implemented on a System-On-Chip.
- The system will be easy to install on posts, fences, and other objects common in an agricultural setting.
- Housing for the system will be durable and able to withstand weather conditions and contact from livestock.

5.2. *Disadvantages and Limitations*

- The proposed system will only measure ammonia, carbon dioxide, methane, nitrous oxide, and hydrogen sulfide.
- The system only interfaces with a web-based application that will be created. Other applications for data analysis will be unsupported.
- The user's device needs to be compatible with the web application.

5.3. *Alternatives*

Alternatives to the Livestock Gas Monitoring System include:

- No gas monitoring sensors could be present in the livestock farm.
- Less gases could be measured by the sensors.
- Gas concentrations could be sampled with a handheld sensor regularly.
- A battery management system could be implemented to provide redundancy.
- Communications are wired rather than wireless.
- The data could be left to be organized and analyzed by the user.

5.4. *Impact*

Economic Impacts:

- By determining the relationship between atmospheric conditions and animal health, this data can inform decision making crucial to keeping livestock healthy.
- Expenses are reduced due to less veterinary visits.
- The farmer yields higher quality meat and other animal products.

Health and Safety Impacts:

- Livestock is at less risk of inhaling toxic concentrations of gases that could lead to injury or death.
- Toxic concentrations of gases can be detected before humans are exposed to them.

Social Impacts:

- Ranchers have less reason to worry about dangerous amounts of certain gases harming their livestock.

Gas Monitor for Animal Farms

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FUNCTIONAL SYSTEM REQUIREMENTS

REVISION – Draft
25 September 2024

Functional System Requirements
for
Gas Monitoring System

Prepared by:

Author Date

Approved by:

Project Leader Date

John Lusher, P.E. Date

Ethan Barnes Date

Change Record

Rev.	Date	Originator	Approvals	Description
0	9/25/2024	[person's name]		Draft Release

Table of Contents

List of Tables

List of Figures

1. Introduction

1.1. Purpose and Scope

The purpose of this document is to outline the detailed system requirements for the Gas Monitoring System. The system aims to measure and store data on the concentrations of gases such as ammonia, carbon dioxide, methane, and hydrogen sulfide. By collecting data about the environments in which animals live, farmers will be able to make informed decisions to improve animal health. Enhanced animal health can lead to reduced veterinary costs, higher meat quality, and increased profits for farmers.

Figure 1. Gas Monitoring System Concept Image

1.2. Responsibility and Change Authority

Requirements can only be changed with the approval of the team leader Joaquin Salas, Professor John Lusher, and Justin Houck. The individual subsystem owner is responsible for the fulfillment of the requirements of their subsystem.

Subsystem	Responsibility
Sensors and Signal Conditioning	Blake Schwartzkopf
Power Distribution and Housing Unit	Matthew Owen
Microcontroller and Data Transmission	Joaquin Salas
Data Management And Web Application	Tanmay Sarkar

Table 1. Subsystem Responsibility

2. Applicable and Reference Documents

2.1. Applicable Documents

The following documents, of the exact issue and revision shown, form a part of this specification to the extent specified herein:

Document Number	Revision/Release Date	Document Title
RFC 8259	2017	JSON Data Interchange Format: Defines the standards for formatting the data transmitted by your microcontroller
IEEE 802.15.4	2006	Standard for Low-Rate Wireless Personal Area Networks (LR-WPANs): For Zigbee and LoRa compatibility
FCC Part 15	2006	Federal Communications Commission Regulations: Governs wireless communication devices to ensure low power emissions and avoid interference with licensed communication services
LoRaWAN 1.0.4 Specification	2020	LoRa Alliance Standard for LoRaWAN® 1.0.4: Wireless Communication Standard for Low-Power, Wide-Area Networks

Table 2. Applicable Documents

2.2. Reference Documents

The following documents are reference documents utilized in the development of this specification. These documents do not form a part of this specification and are not controlled by their reference herein.

Document Number	Revision/Release Date	Document Title
EN 60529	N/A	Ingress Protection Rating

Table 3. Reference Documents

2.3. Order of Precedence

In the event of a conflict between the text of this specification and an applicable document cited herein, the text of this specification takes precedence without any exceptions.

All specifications, standards, exhibits, drawings or other documents that are invoked as “applicable” in this specification are incorporated as cited. All documents that are referred to within an applicable report are considered to be for guidance and information only, except ICDs that have their relevant documents considered to be incorporated as cited.

3. Requirements

3.1. System Definition

This section outlines the requirements for the Gas Monitoring System, which is essential to make sure all system needs of design, functionality, and performance are met. The Gas Monitoring System is a durable, accurate, and reliable instrument for monitoring concentrations of various gasses commonly found in industrial livestock environments. It allows users to view concentration levels in a historian to conduct further research and improve livestock production. The Gas Monitoring System has four subsystems: Gas Sensors and Signal Conditioning, Power and Housing Unit, Microcontroller and Data Transmission, and Data Management and Web Application. We have set these requirements outlined in this document to ensure each subsystem will contribute to the overall functionality of the system.

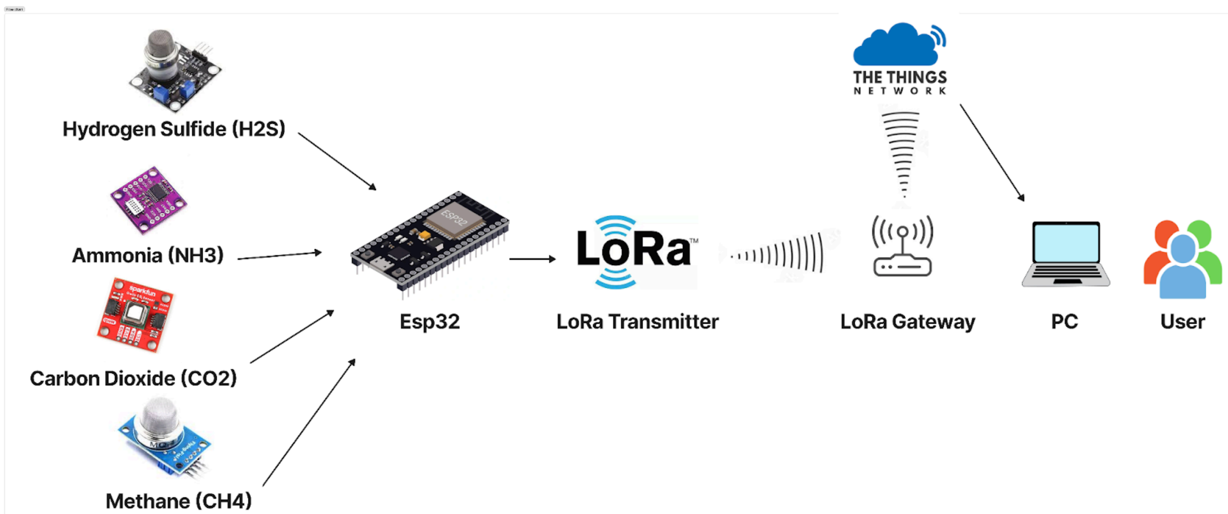

Figure 2. Block Diagram of System

Gas sensors measure methane, ammonia, carbon dioxide, and hydrogen sulfide, with three providing analog outputs and one offering digital I2C output. The analog outputs are converted into digital SPI signals using an AD7718 analog-to-digital converter, allowing the ESP32 microcontroller to gather and process the data. The system is powered by a battery management unit housed in a weather-resistant casing to protect the internal components from harsh farm conditions. The ESP32 microcontroller is also responsible for communicating with the LoRa transmitter (SX1278), which sends the collected data to a nearby LoRaWAN gateway for long-range transmission.

Once transmitted, the data is sent from the LoRa gateway to a central server using protocols such as MQTT, HTTP, or TCP/IP. The server stores the data for long-term analysis and provides historical records for real-time monitoring via a web application. Additionally, a machine learning model analyzes the collected data, offering predictive insights into how the gas levels impact livestock health. This allows farmers to make informed decisions that can improve the living conditions of the animals and increase farm productivity while reducing costs.

3.2. Characteristics

3.2.1. Functional / Performance Requirements

3.2.1.1. Gas Detection Range of Ammonia

The Gas Monitoring System shall be able to detect ammonia between 5 and 500 ppm.

Rationale: The average amount of ammonia found in poorly ventilated animal farms is approximately 100-200 ppm.

3.2.1.2. Gas Detection Range of Carbon Dioxide

The Gas Monitoring System shall be able to detect carbon dioxide between 400 and 5000 ppm.

Rationale: The average amount of carbon dioxide found in animal farms is approximately 1000-3000 ppm.

3.2.1.3. Gas Detection Range of Methane

The Gas Monitor System shall be able to detect methane between 300 and 10000 ppm.

Rationale: The average amount of methane in the respiration air of cattle is 1000 ppm.

3.2.1.4. Gas Detection Range of Hydrogen Sulfide

The Gas Monitor shall be able to detect hydrogen sulfide between 1 and 200 ppm.

Rationale: The average amount of hydrogen sulfide in animal farms is 2-10 ppm.

3.2.1.5. Gas Detection Error

The Gas Monitoring System concentration readings for each gas shall not be more than 10% off from the actual gas concentration.

Rationale: The system should be able to detect a good estimate of the gas concentration in ppm. 10% is a reasonable deviation for the budget allocated to this project.

3.2.1.6. Data Transmission Rate

The microcontroller will transmit data between 30 seconds and 1 minute.

Rationale: The data transmission rate will be adjusted depending on the users requirements.

3.2.2. Physical Characteristics

3.2.2.1. Mass

The mass of the Gas monitoring System shall be less than or equal to 4 kilograms.

Rationale: The gas monitoring system must be lightweight to be mounted easily. It must be easily installed and accessible without too much unnecessary weight.

3.2.2.2. Volume Envelope

The volume of the Gas monitoring System shall be less than or equal to 15 inches in height, 15 inches in width, and 4 inches in length.

Rationale: The gas monitoring system needs to be able to be mounted inside of animal farms without affecting the animals.

3.2.2.3. Water Resistance

The Gas Monitoring System shall have water resistant housing to protect the electrical elements. The sensors should be able to detect gases outside of the case.

Rationale: IP 31 is a standard rating that offers protection against water and foreign objects. Some animal farms will not be indoors. Electrical components need to be protected in outdoor conditions.

3.2.2.4. Collision Resistance

The Gas Monitoring System shall have collision resistant housing to protect the electrical elements. The sensors should be able to detect gases outside of the case.

Rationale: Animals will likely collide with the system, the housing needs to protect the electrical components from these collisions.

3.2.2.5. Mounting

The Gas Monitoring System will support multiple options for mounting, including but not limited to pole, wall, and fence installations. The exact method of mounting will be determined after a tour of the animal farms has taken place.

Rationale: Many of the animal farms may vary significantly from one another, thus a flexible mounting system will be needed to adapt to the specific needs of each farm.

3.2.3. Electrical Characteristics

3.2.3.1. Voltage Input Range

The input voltage for the Gas Monitoring System will be AC voltage. The voltage will be 120V ± 10%, 60 Hz.

Rationale: Standard outlets where this system will be plugged in are typically 120v AC at 60 Hz. The system will need to accommodate this input voltage.

3.2.3.2. AC to DC Conversion

The Gas Monitoring System will have an internal AC to DC converter circuit that will output voltages ranging from 1V to 12V of DC power to internal systems.

> *Rationale: The internal subsystems will operate and require lower DC voltages than what is inputted. An internal conversion is required to provide stable voltage to the rest of the system.*

3.2.3.3. Buck-Boost Voltage Regulation

The system will include the required voltage converters that can step down the DC voltage received to varying values of voltage needed to power other internal components.

> *Rationale: Buck-boost converter is needed in order to provide a consistent and stable voltage supply to important components of the system.*

3.2.3.4. Voltage Filters

The power subsystem will have the required voltage filter circuits with the purpose of suppressing noise and any interference from the output of the buck boost circuits.

> *Rationale: We expect some farm environments to have noisy electrical systems so we must ensure all components are free from anything that can negatively affect the performance of electronics.*

3.2.4. Output

3.2.4.1. Data Output

The Gas Monitoring System shall include a wireless interface for transmitting gas concentration data to a central server. The system will support the LoRaWAN protocol for long-range communication.

> *Rationale: Data will be transmitted over LoRaWAN to a centralized server for visualization and analysis. LoRaWAN offers long-range, low-power communication, which is essential for agricultural applications where devices may be far from the receiver.*

3.2.4.2. Diagnostic Output

The Gas Monitoring System shall include a diagnostic interface to monitor system health and sensor functionality.

> *Rationale: The diagnostic output will help with debugging and allow for real-time error detection.*

3.2.4.3. Reliable Data handling & Error checking

The Gas Monitoring System will ensure that the data received from the gateway is all in the correct format (JSON) and that none of it was lost during transmission.

> *Rationale: This could be done using buffer handling and timestamps for when the measurements are being taken. The efficiency of getting the data from the gateway to the server is also crucial in reliable data handling. Error handling is also included in this*

requirement. It will be crucial to ensure that the data being received has not been corrupted or contains invalid values.

3.2.4.4. Scalable Storage

The Gas Monitor will have a scalable server for increased amounts of data over time.

Rationale: This requirement is crucial because one of the key components of the system is being able to handle large volumes of data over time. The long-term goal of this is to see the effects of certain gas amounts on the health of the animal. MySQL will be used because it supports horizontal scaling. In order to optimize storage use, the system shall also automatically delete older data.

3.2.4.5. Database and Web Application Security

The Gas Monitoring system will encrypt communication between the LoRa Gateway, server, and web application.

Rationale: It is important that the gas data is encrypted so that there is no unauthorized use. In addition to this, the web application will have a secure authentication mechanism so that only the intended users can access the data.

3.2.4.6. Overall System Latency

The Gas Monitoring System will aim to concurrently update the web application with gas value updates as they are ready.

Rationale: The aim is to have the data be updated in an efficient manner by using real time API handling. It may not be live updating but we aim to have a refresh of data every 5 minutes at the maximum. This means that the user can have up to date information regarding the gas abundances in a certain location.

3.2.4.7. User Login Privacy

The Gas Monitoring System will comply with several user breach laws that apply in Texas.

Rationale: Because the system will have role-based access and the user will have to create an account, the system will have to adhere to regulations such as the Texas Privacy Protection Act (HB 3746) and the Texas Identity Theft Enforcement and Protection Act (ITEPA).

3.2.4.8. Thermal

The Gas Monitoring System will need to work properly in an environment with temperatures ranging from - 20°F to 110°F

Rationale: Animal farms can have a wide range of temperatures. Sponsor specified the need for the gas monitoring system to be durable and have the ability to work in a large range of temperatures.

3.2.4.9. Humidity

The Gas Monitoring System will need to work properly in an environment with humidity ranging from 0% to 100%.

Rationale: The outdoor environment will have extreme humidity variations, from dry to high moisture levels. The system must operate reliability in these conditions to ensure accurate gas measurements.

4. Support Requirements

The system will include all the sensors, a microcontroller which will communicate with the central database, and a web application that will gather the data and visualize it. The system will also be placed in a housing system that will be able to be plugged into a wall outlet for power distribution. The only requirement for the user of the system will be to have a device with an internet connection. If possible, the user being able to have basic technological skills could be necessary. This would help the user be able to read the data from the web application and draw a conclusion based on it. An additional goal is to have the system be able to output a small summary of what the raw data shows, along with possible actions that could be taken based on it.

Appendix A: Acronyms and Abbreviations

V	Voltage
AC	Alternating Current
DC	Direct Current
EMC	Electromagnetic Compatibility
PPM	Parts Per Million
PCB	Printed Circuit Board
Hz	Hertz
kHz	Kilohertz
A	Amps
mA	Milliamp
SPI	Serial Peripheral Interface
I2C	Inter-Integrated Circuit
MQTT	MQ Telemetry Transport
HTTP	Hypertext Transfer Protocol
TCP/IP	Transmission Control Protocol/Internet Protocol

Appendix B: Definition of Terms

Gas Monitor for Animal Farms

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Blake Schwartzkopf

INTERFACE CONTROL DOCUMENT

REVISION – Draft
25 September 2024

Interface Control Document
for
Gas Monitoring System

Prepared by:

Author Date

Approved by:

Project Leader Date

John Lusher II, P.E. Date

Ethan Barnes Date

Change Record

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Table of Contents

List of Tables

List of Figures

1. Overview

The Interface Control Document (ICD) for the Gas Monitoring System will outline how each of the subsystems within the project will interface with one another. It will provide a detailed summary of all physical, electrical, and data interfaces between each subsystem. This document explains all inputs and outputs of each subsystem to ensure that there is compatibility between each subsystem. Lastly, this document acts as a verification tool during development and testing, helping ensure the system works as expected when all subsystems are integrated.

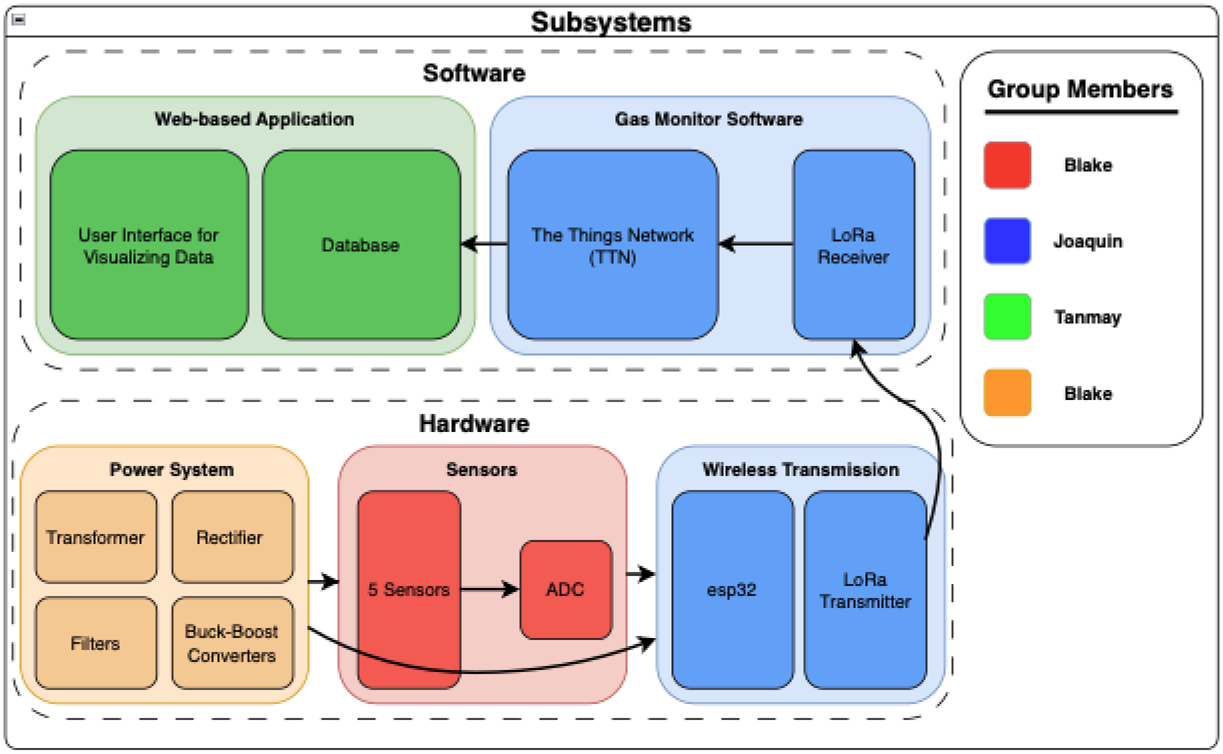

Figure 1. Subsystems

2. References and Definitions

2.1. References

- LoRaWAN Protocol Specifications (LoRa Alliance):
    - LoRaWAN Specification v1.0.4
    - LoRaWAN Specification v1.1
    - LoRaWAN Regional Parameters
- The Things Network (TTN) Documentation:
    - The Things Stack (LoRaWAN Network Server)
    - The Things Stack API Reference
- Wireless Communication Regulations (FCC):
    - FCC Part 15: Devices should not interfere with licensed communication devices and must meet low-power standards
    - EMI Compliance: Ensure that the device does not generate harmful EMI that could impact other devices.

2.2. Definitions

V	Voltage
AC	Alternating Current
DC	Direct Current
EMC	Electromagnetic Compatibility
PPM	Parts Per Million
PCB	Printed Circuit Board
Hz	Hertz
kHz	Kilohertz
A	Amps
mA	Milliamp
I2C	Inter-Integrated Circuit
SPI	Serial Peripheral Interface

3. Physical Interface

Provide details on the physical interface. Examples are:

3.1. Weight

3.1.1. Main PCB

Component	Weight	Number of Items	Total Weight
MQ-137 Ammonia Sensor	4.070 g	1	4.070 g
SCD41-D-R2 Carbon Dioxide Sensor	0.600 g	1	0.600 g
MQ-4 Methane Sensor	5.000 g	1	5.000 g
MQ136 Hydrogen Sulfide Sensor	9.000 g	1	9.000 g
HDC1080DMBR Temperature Sensor	0.160 g	1	0.160 g
AD7718 Analog to Digital Converter	0.403 g	1	0.403 g
esp32 dev board v4	10.000 g	1	10.000 g
LoRa Module	8.000 g	1	8.000 g

Table 1: Main PCB Weight

3.1.2. Power PCB

Component	Weight	Number of Items	Total Weight
Transformer TCT50-03E07K	907.2 g	1	907.2 g
Diode Bridge Rectifier	36g	1	36g
Buck-Boost	TBD	TBD	TBD

Table 2: Power PCB Weight

3.2. Dimensions

3.2.1. Dimensions of Sensor Subsystem

Component	Length	Width	Height	Diameter
MQ-137 Ammonia Sensor	N/A	N/A	24 mm	19 mm
SCD41-D-R2 Carbon Dioxide Sensor	10.1 mm	10.1 mm	6.5 mm	N/A
MQ-4 Methane Sensor	N/A	N/A	24 mm	19 mm
MQ136 Hydrogen Sulfide Sensor	N/A	N/A	24 mm	19 mm
HDC1080DMBR Temperature Sensor	3.1 mm	3.1 mm	0.8 mm	N/A
AD7718 Analog to Digital Converter	9.7 mm	4.4 mm	1.05 mm	N/A

Table 3: Dimensions of Sensor Subsystem

3.2.2. Dimension of Microcontroller Subsystem

Component	Length	Width	Height	Diameter
ESP32-S2-WROVER-I	18mm	31mm	3.3 cm	N/A
LoRa Module	28 mm	20.3 mm	5 mm	N/A

Table 4: Main PCB Weight

3.2.3. Dimensions of Power Subsystem

Component	Length	Width	Height
Transformer TCT50-03E07K	92.46mm	56.67mm	57.40mm
Diode Bridge Rectifier	TBD	TBD	TBD
Buck-Boost	TBD	TBD	TBD

Table 5: Dimensions of Power Subsystem

3.3. Mounting Locations

The Gas Monitoring System will be installed across industrial agriculture settings in the state, ensuring unobstructed access to the air being measured. The monitor will be mounted on posts, fences, or other structures commonly found in animal farms. Using the LoRaWAN wireless protocol, the system can transmit data efficiently from distances of 10-15 km, making it ideal for deployment in remote locations.

Figure 2. Concept Image of Mounting Location

4. Thermal Interface

The Gas Monitoring System will operate in industrial agricultural environments where temperature fluctuations are common. Due to the low power consumption of the sensors, microcontroller, and transmitter, active cooling is not required. Passive thermal management through the housing material will ensure any heat generated internally is dissipated and effectively. The design will allow the system to function reliably in both high and low-temperature conditions.

5. Electrical Interface

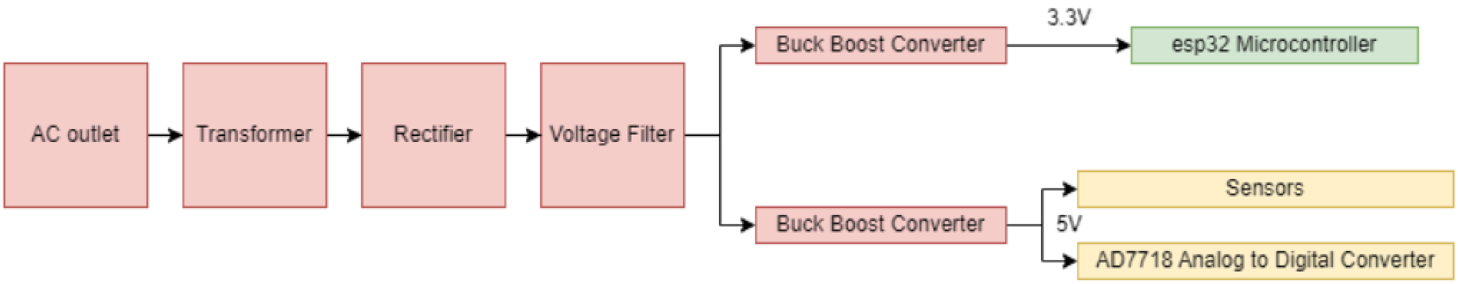

Figure 3: Electrical Interface

5.1. Primary Input Power

All power necessary for the Gas Monitoring System will be supplied through a 120 V AC connection with a standard US wall outlet. Inputted power will be sent to the power PCB subsystem where it will be stepped down, rectified, and filtered. The DC voltage will then be stepped down to 3.3V for the microcontroller subsystem and 5V for the sensor subsystem.

5.2. Voltage and Current Levels

5.2.1. Maximum Values

Component	Voltage (V)
MQ-137 Ammonia Sensor	5
SCD41-D-R2 Carbon Dioxide Sensor	5
MQ-4 Methane Sensor	5
MQ136 Hydrogen Sulfide Sensor	5
HDC1080DMBR Temperature Sensor	5
AD7718 Analog to Digital Converter	5
ESP32-S2-WROVER-I	3.3

Table 6: Voltage and Current Level

5.3. Signal Interfaces

The Gas Monitoring System utilizes both analog and digital signal interfaces. Three gas sensors provide analog outputs, which are converted to digital signals using AD7718 analog-to-digital converter (ADC). These SPI digital outputs, along with the I2C digital outputs from other sensors, are transmitted to the ESP32 microcontroller for processing. The LoRa module will be connected to the appropriate GPIO pins on the ESP32 and will transmit the processed data using the LoRaWAN wireless protocol to a nearby gateway, which forwards the data to a database for data visualization.

5.4. User Control Interface

The user control interface is a web application that interacts with the system's database. It allows the user to adjust the data transmission rate, view live data streams, access historical data, and interact with the diagnostic interface. On the web application, the user will also have access to downloading the current data that is on it, and have the freedom to draw conclusions based on that.

6. Communications / Device Interface Protocols

6.1. *Wireless Communications*

6.1.1. LoraWAN

The microcontroller will use the LoraWAN protocol to transmit sensor data. The microcontroller will connect to a LoraWAN transmitter, which sends the data to a Lora gateway. From there, data is forwarded to The Things Network (TTN) for storage and accessing.

6.1.2. Database

The collected data will be received in The Things Network (TTN), which provides global coverage for LoraWAN networks. This setup allows for secure, wireless storage for future access to the data.

6.1.3. WiFi usage

The Lora gateway will transmit the data to TTN using the internet, which can then be accessed using WiFi-accessible devices.

6.1.4. Web Application

The web application will retrieve the data from TTN using HTTP requests, and it will be sent in a .JSON format, making the data easy to handle once it reaches the web application.

Gas Monitor for Animal Farms

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Blake Schwartzkopf

SCHEDULE AND VALIDATION

REVISION – Draft

Schedule:

Work	Date	Owner
Understand project and requirements	8/27/2024	All
Research	9/13/2024	All
Complete Conops	9/15/2024	All
Complete FSR	9/26/2024	All
Complete ICD	9/26/2024	All
Complete Validation Plan	9/26/2024	All
Complete Schedule	9/26/2024	All
Order Parts	9/27/2024	All
Learn about HTML/JavaScript/MySQL and compare	9/30/2024	Tanmay
Learn about JSON/Begin basic structure for Web App	9/30/2024	Tanmay
Complete Subsystem Introduction Project	9/30/2024	All
Test Wireless Communications	10/1/2024	Joaquin
Mid-Term Presentation	10/2/2024	All
Create part symbols	10/3/2024	Blake
Create part footprints	10/3/2024	Blake
Begin creating a test environment for data handling	10/7/2024	Tanmay
Ensure that Web App can retrieve data from TTN	10/7/2024	Tanmay
Design schematic	10/8/2024	Blake
Implement Sensors	10/9/2024	Joaquin
Wireless Communications to Server	10/9/2024	Joaquin
Design Circuit Schematic	10/10/2024	Matthew
PCB routing	10/10/2024	Blake
Web Application be able to retrieve/visualize test data	10/14/2024	Tanmay
Final design check	10/15/2024	Blake
Order PCB	10/15/2024	Blake
Build Circuit In Altium (FootPrints, Schematic, routing)	10/18/2024	Matthew
Status Update Presentation	10/21/2024	All
Learn to solder	10/22/2024	Blake
Program AD7718	10/22/2024	Blake
Final Design Check	10/23/2024	Matthew

Order PCB from PCB Way	10/25/2024	Matthew
Order parts	10/25/2024	Matthew
Improve Web App Aesthetics/Functionality/Efficiency	10/28/2024	Tanmay
Finish Implementing Sensors	10/29/2024	Joaquin
Finnish Communications to Server	10/29/2024	Joaquin
Solder parts onto PCB	10/29/2024	Blake
Solder parts onto PCB	11/4/2024	Matthew
Test sensor outputs for PCB	11/8/2024	Blake
Fully Functioning Database + Web App	11/15/2024	Tanmay
Test AD7718	11/15/2024	Blake
Final Presentation	11/18/2024	All
Test and Debug PCB	11/26/2024	Matthew
Final Demo	11/26/2024	All
Final Report	12/5/2024	All

Validation Plan:

Task	Specification	Result	Owner
Data Updating	<5 Mins		Tanmay
Data Transmission	<5 Seconds		Tanmay
Gas Detection Error	< 10%		Blake
Analog to Digital Conversion	Conversion successful		Blake
Voltage Output	5V, 3.3V		Matthew
Voltage From Transformer	12V AC		Matthew
LoRa Module Transmit	Transmits to database		Joaquin
Transmitter Range	100 feet		Joaquin
Transmitter Frequency	30 sec - 1 min		Joaquin