POLITEKNIK SULTAN SALAHUDDIN ABDUL AZIZ SHAH

DETECT GAS TUBING LEAKAGE FOR VENTILATOR

THARISHINI RAVI

(08DEU21F2057)

ELECTRICAL ENGINEERING DEPARTMENT

SESSION I : 2024/2025

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This final report is submitted to the Electrical Engineering Department in fulfilment of the requirements for the award of the Diploma of Medical Electronic Engineering

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DECLARATION OF PROJECT REPORT AND COPYRIGHT

DETECT GAS TUBING LEAKAGE FOR VENTILATOR

1. I, **THARISHINI RAVI(08DEU21F2057** is final semester in **Diploma in Electronic Engineering (Medical)**, D**epartment of Electrical, Politeknik Sultan Salahuddin Abdul Aziz Shah**, address **Persiaran Usahawan, Seksyen U1, 40150 Shah Alam, Selangor**. (After this as 'As Polytechnic').

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THARISHINI RAVI) ....
(Identification Card No.: 030601101358)) THARISHINI RAVI

Before me,)
NOR KHARUL AINA BINTI MAT DIN) ....
(As a project supervisor at (date): …25.11.2024…..)…… **NOR KHARUL AINA BINTI MAT DIN**

ACKNOWLEDGEMENT

In preparing this project I have encountered and learnt so many new experiences. I would like to thank my supervisor, Puan Nor Kharul Aina binti Mat Din for his excellent advice, guidance and motivation. I am also very thankful to my classmate, friends and other people that contributed to my project. Without their contribution, I won't be able to finish my project on time.

Finally, I learnt a lot in Politeknik Sultan Salahuddin Abdul Aziz Shah (PSA), I owe sincere and earnest thankfulness for the unforgettable and unique experience of my life. I am also very thankful to my family for their supports, especially throughout this period of my life and kept me going all the way through my study.

ABSTRAK

Kajian ini memberi tumpuan kepada pengesanan kebocoran paip gas dalam ventilator, satu isu kritikal yang boleh menjejaskan keselamatan pesakit dan keberkesanan pengudaraan mekanikal. Penyelidikan ini meneroka pelbagai kaedah dan teknologi, seperti penderia tekanan, penderia akustik, dan algoritma pembelajaran mesin, untuk mengesan kebocoran dalam paip gas. Kaedah-kaedah ini bertujuan untuk menyediakan sistem amaran awal bagi memberitahu penyedia penjagaan kesihatan tentang risiko yang berpotensi, dengan itu memastikan pengudaraan yang berterusan dan berkesan. Pelaksanaan mekanisme pengesanan kebocoran dalam ventilator boleh meningkatkan kebolehpercayaan dan keselamatan peranti sokongan pernafasan dengan ketara.

ABSTRACT

This study focuses on the detection of gas tubing leakage in ventilators, a critical issue that can compromise patient safety and the effectiveness of mechanical ventilation. The research explores various methods and technologies, such as pressure sensors, acoustic sensors, and machine learning algorithms, to identify leaks in the gas tubing. These methods aim to provide early warning systems to alert healthcare providers to potential risks, thereby ensuring continuous and effective ventilation. The implementation of leak detection mechanisms in ventilators can significantly enhance the reliability and safety of respiratory support devices.

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CHAPTER 1
INTRODUCTION

1.1 Introduction

Detecting gas tubing leakage in ventilators is crucial for ensuring patient safety and maintaining the efficiency of respiratory support systems. Ventilators, which are essential in critical care, depend on a closed and secure system to deliver precise volumes of gas to patients. Any leakage in the gas tubing can compromise the ventilator's functionality, potentially leading to insufficient ventilation and adverse patient outcomes. This document aims to explore the methodologies and technologies employed in identifying and addressing gas tubing leaks in ventilators. By understanding these techniques, healthcare professionals can better safeguard the integrity of ventilation systems and ensure optimal patient care.

1.2 Project Background

Detecting gas tubing leakage in ventilators is critical for patient safety and equipment efficiency. Gas leaks can lead to inadequate ventilation, exposing patients to hypoxia or other respiratory complications. Modern ventilators often use advanced sensors and algorithms to detect leaks by monitoring pressure, flow, and volume inconsistencies. Techniques such as pressure decay testing, ultrasonic leak detection, and infrared imaging are commonly employed. Pressure decay involves sealing the system and observing pressure drops, while ultrasonic and infrared methods detect the sound or heat emitted by leaking gas. Ensuring leak detection mechanisms are in place is essential for maintaining the reliability and effectiveness of ventilators.

1.3 Problem Statement

Detecting gas tubing leakage in a ventilator is crucial for ensuring patient safety and device functionality. The challenge lies in developing a system that can accurately identify leaks in the tubing, which could compromise the delivery of oxygen or other gases to the patient. This system needs to be sensitive enough to detect even small leaks, reliable to minimize false alarms, and ideally, it should provide real-time monitoring to promptly alert healthcare professionals to any issues. Additionally, the detection method should be non-invasive to avoid interfering with the normal operation of the ventilator and ensure uninterrupted patient care.

1.4 Project Objective

The objectives of this project are:

a) Develop sensor technology capable of detecting gas leaks in ventilator tubing with high sensitivity and accuracy.

b) Investigate the most common types and locations of gas leaks in ventilator tubing to inform sensor design and placement.

c) Explore methods for integrating the gas leakage detection system seamlessly into existing ventilator designs without compromising functionality or reliability.

1.5 Project Scope

1. This Project is focusing on detect gas tubing leakage for ventilator
2. The emphasis is to do it save it in the IoT technology.
3. The main controller is using Arduino.

1.6 Problem Significance

Detecting gas tubing leakage in ventilators is crucial for ensuring patient safety and maintaining the effectiveness of ventilation therapy. Leakage can compromise the delivery of oxygen and other gases to the patient, leading to inadequate ventilation and potential harm. Implementing reliable detection mechanisms helps healthcare providers promptly identify and address leaks, thereby safeguarding patient wellbeing and maintaining the integrity of critical medical equipment. Ultimately, this project significantly contributes to enhancing the quality of care and reducing the risk of adverse events in medical settings.

1.7 Definition of Term or Operation

Gas tubing leakage detection in a ventilator refers to the process of identifying and addressing any unintentional escape of gases (like oxygen or air) from the ventilator's tubing system, which is essential for ensuring proper ventilation to a patient. This leakage may occur due to cracks, loose connections, or wear-and-tear in the tubing, and it can compromise the efficacy of ventilation therapy by delivering inadequate gas volume or inconsistent pressures to the patient. Detection involves monitoring pressure levels, flow rates, and alarms that indicate volume discrepancies, ensuring immediate response to maintain patient safety and treatment accuracy.

1.8 Summary

This chapter stated the fundamental concept of my project and the ideas behind it. It emphasizes the problem statement and objectives of making this project, as well as the scope and limitations of it, highlighting the significance of this project and serving as an introduction to my project and this proposal. It also cites research on similar topic in the past that serve as a foundation for my projects.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

With the increased interest in utilizing IoT technology in the medical field, Detecting gas tubing leakage in ventilator systems is critical for ensuring patient safety and maintaining the efficacy of respiratory support. Inadequate detection of leaks can lead to compromised air delivery, affecting patient oxygenation and ventilation. Therefore, reliable methods for early detection and localization of leaks are essential. This literature review aims to explore existing techniques, technologies, and advancements in gas tubing leakage detection for ventilator systems, highlighting their strengths, limitations, and potential areas for further research and improvement.

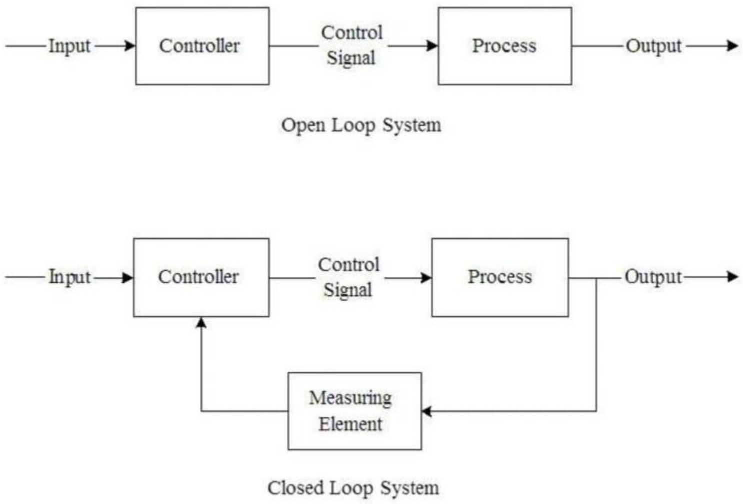
2.2 (Literature Review Topic 1)

Detecting gas tubing leakage in ventilators is a critical aspect of ensuring patient safety and device efficacy. Literature on this topic likely explores various methods for detecting leaks, such as pressure sensors, acoustic monitoring, and visual inspection techniques. Additionally, research may delve into the development of automated systems for real-time detection and notification of leaks to healthcare providers. Understanding the current state of research can inform the improvement of existing detection methods and the development of new technologies to enhance patient care.

2.3 Control System (Literature Review Topic 2)

Control System theory has played an important role in computing system. The development of computing in computer science has become an enabler for the widely used controller in control systems to migrate.

Figure 2.1 Block diagram of open loop and closed loop system



2.3.1 Microcontroller (Literature Review Topic 2)

A microcontroller is a compact integrated circuit (IC) that contains a processor core, memory, and various peripherals, all housed within a single chip. It's essentially a small computer optimized for embedded applications. They are favoured for their small size, low power consumption, and cost-effectiveness, making them ideal for controlling simple to moderately complex tasks in real-time.

2.4 Arduino (Literature Review Topic 3)

Arduino is an open-source electronics platform that consists of both hardware and software components. It's designed to make it easy for beginners and professionals alike to create interactive projects and prototypes. Its simplicity, versatility, and affordability have made it a popular choice for both beginners and experienced makers alike.

2.5 Related Project

A related project for detecting gas tubing leakage in ventilators would involve developing a sensor-based monitoring system integrated into the ventilator's gas delivery pathway. This system would utilize highly sensitive pressure, flow, and gas concentration sensors to continuously monitor for any discrepancies that could indicate a leak. Advanced algorithms could analyze sensor data in real-time, alerting healthcare providers when a leak occurs, ensuring patient safety. The system would need to be reliable, precise, and capable of detecting even small leaks to prevent potential hazards in critical care environments. Additionally, the project could explore wireless communication features for remote monitoring and quick interventions.

2.5.1 AI GAS LEAKAGE DETECTOR(Project 1)

Project 1 focused on using artificial intelligence (AI) and machine learning algorithms to detect patterns indicative of gas leakage in ventilator systems. By analyzing sensor data, the AI model could predict and identify leaks, even in cases where variations were subtle. This predictive approach allowed for proactive maintenance and minimized patient risks, ensuring ventilator integrity at all times.

2.5.2 GAS LEAKAGE DETECTOR SENSOR-BASED(Project 2)

Project 2 involved the development of an advanced sensor-based gas leakage detection system. It incorporated smart flow sensors and pressure differential technology to identify minute gas leaks in ventilator tubing. The system featured real-time alerts and detailed data logging, allowing for comprehensive monitoring of ventilator performance and safety

2.6 Comparison of Project

Project 2 overall uses more electricity because of the fact that it does not have a built-in battery. Project 2 offered a more straightforward detection mechanism with sensor-based alerts that provided instant feedback. In contrast, Project 1 emphasized a predictive AI-driven approach, which analyzed trends and patterns to identify potential leaks before they became critical. While Project 2 excelled in immediate detection and response, Project 1 prioritized long-term prevention and predictive maintenance, potentially reducing maintenance costs and enhancing overall system reliability.

Table 2.2 Comparison between previous projects

Comparison	Project 1	Project 2	Proposed Project
Microcontroller	None	Arduino Uno	Arduino Nano
Cost	~RM 1600	RM 80	RM 80
Size	100cm x 60cm x 30cm	80cm x 40cm x 30 cm	30cm x 15cm x 15cm
Sustainability to the environment	Using Battery	Using Direct Power Supply	Using Direct Power Supply

2.7 Summary

Detecting gas tubing leakage in ventilators is critical to patient safety and operational efficiency. Project 2 utilized a real-time sensor-based approach for instant leak detection, while Project 1 leveraged AI to predict and detect leaks proactively. Both approaches offer valuable solutions, with Project 2 excelling in immediate responsiveness and Project 1 providing a predictive edge for proactive maintenance. The optimal solution may involve integrating both technologies for comprehensive monitoring and enhanced ventilator reliability.

CHAPTER 3
METHODOLOGY

3.1 Introduction

To realize this Project as a product that ready to use with safety characteristic, a very comprehensive plan is undertaking. A step by step procedure is done so that the Project can be completed in time. This include design the mechanical part, circuit design testing and verification.

3.2 Project Design and Overview

As mention in the previous chapter, the designed controller is using a closed-loop system with Arduino as the main controller. The design of the controller circuit using Arduino realizes using Proteus Software and then convert to PCB circuit.

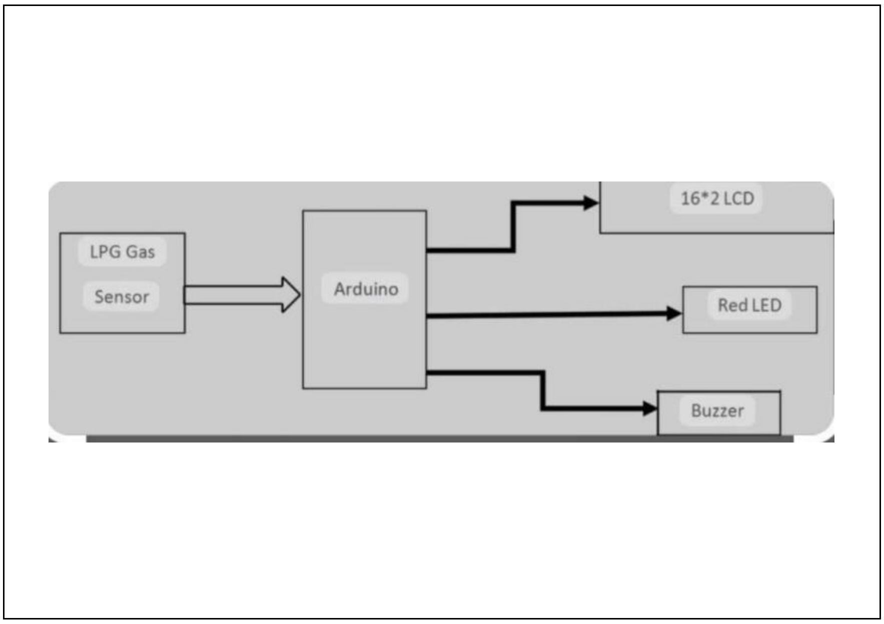


Figure 3.1 Process flow of the project

Below is Figure 3.2 which show the Gantt Chart that represents the planning and early implementation of my project. Figure 3.3 shows a second Gantt Chart that goes over the actual development of the project.

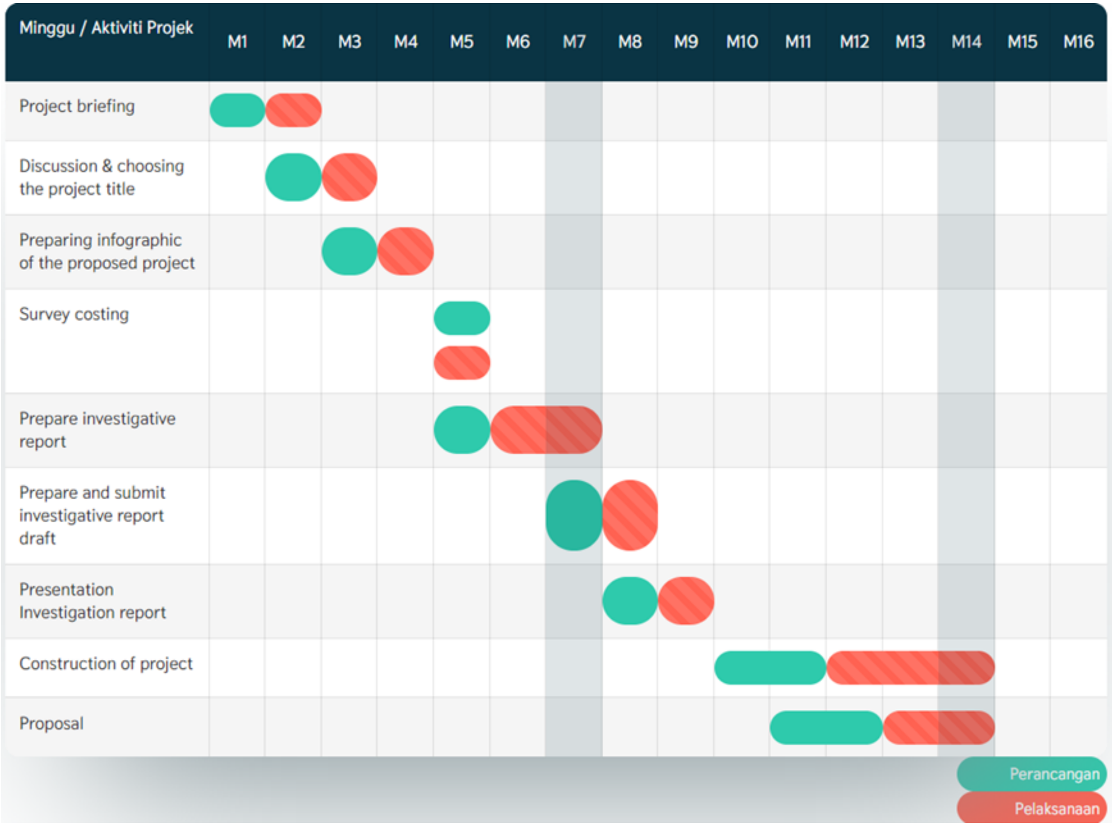


Figure 3.2 Gantt Chart (Project 1)

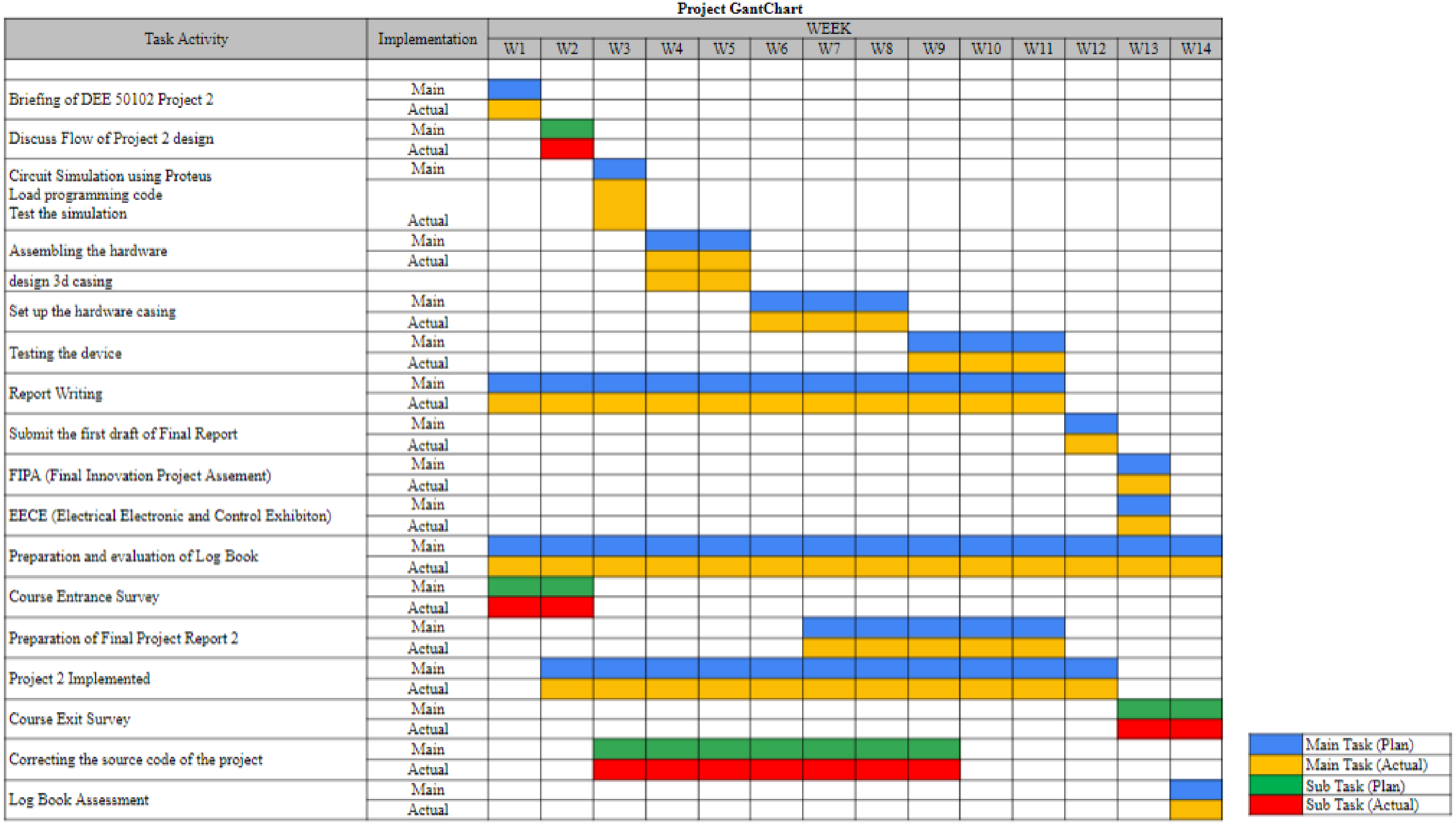


Figure 3.3 Project GantChart

The first Gantt Chart represents Project 1, where I am still planning over the overall design and inner working of my project. During Project 1, I still do not have a clear view of what the final product would be like, only a vague idea. Nonetheless, I keep developing the idea until I have a solid foundation of the project. Such as the materials used, the final design, the connection issue, the power sources as well as the software implementation.

The second Gantt Chart represents Project 2, where I acted on what was planned and started acquiring the necessary components needed to build the project. Not only the hardware, but the software programming and connection as well.

3.2.1 Block Diagram of The Project

3.4 Shows the block diagram of the project. This block diagram explain the connection between each core components and how the product is supposed to function.

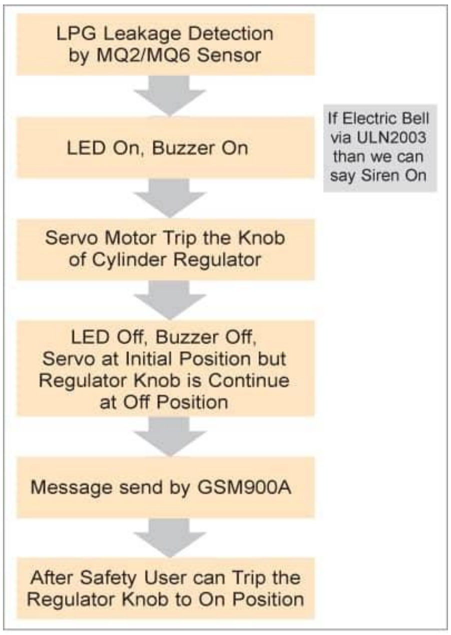


Figure 3.4 Block Diagram of the module

3.2.2 Project Flow Chart

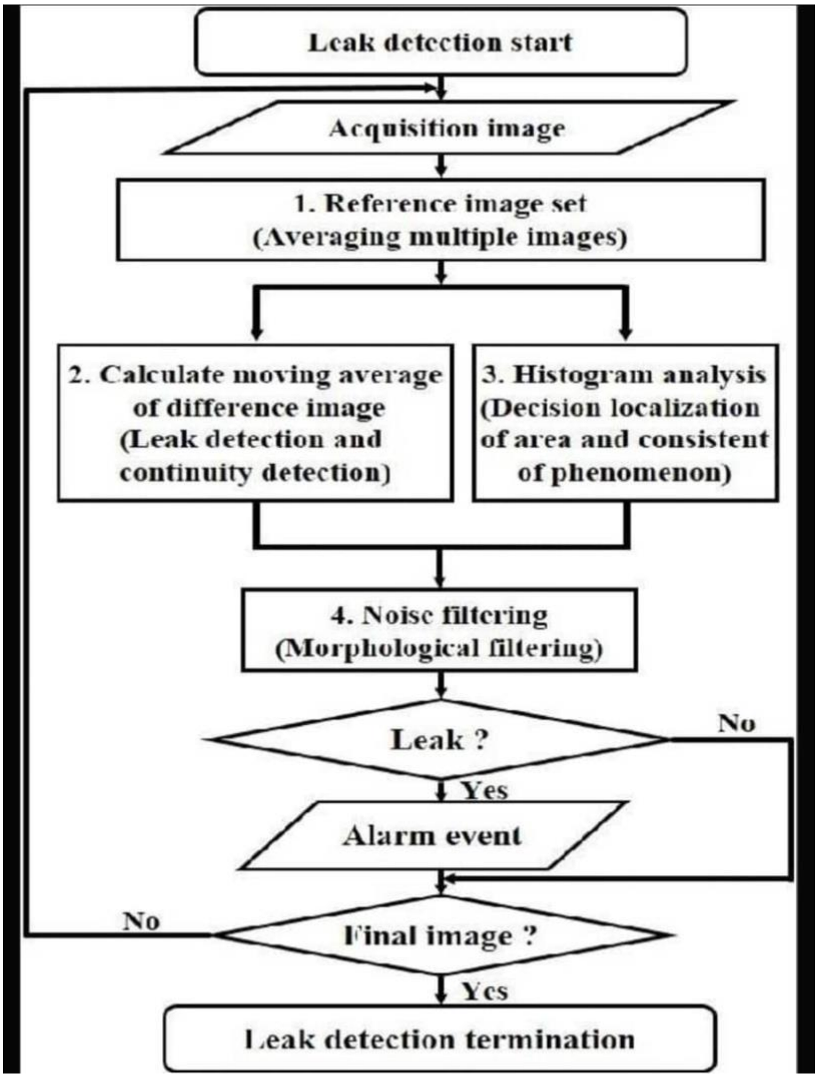


Figure 3.5 Flow chart of the module/system

3.3 Project Hardware

As mentioned in the previous chapter, the designed controller is using Arduino Nano as the microcontroller of this circuit To detect gas tubing leakage for a ventilator project, you would typically employ pressure sensors along the tubing's length. These sensors monitor pressure changes, indicating potential leaks. Additionally, incorporating flow sensors could detect abnormal flow rates, hinting at leaks or blockages. Integrating these sensors with a microcontroller or a dedicated monitoring system allows for real-time monitoring and alerts, ensuring prompt intervention to maintain the ventilator’s functionality and safety.

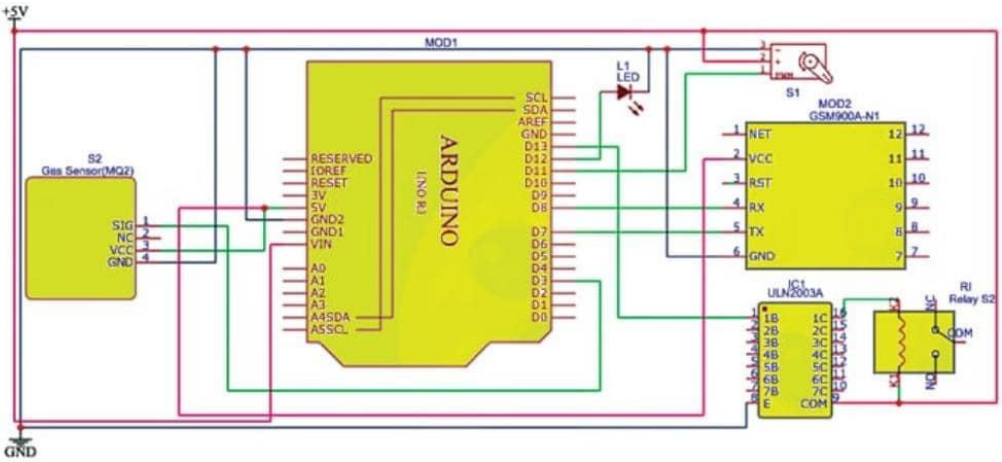


Figure 3.6 Circuit diagram

3.3.1 Schematic Circuit

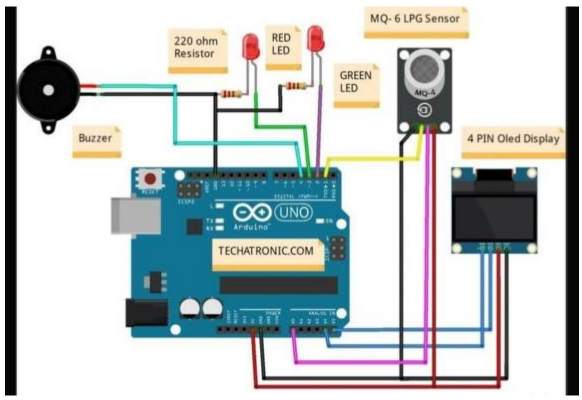


Figure 3.7 Schematic circuit

3.3.2 Description of Component 1

Component 1

Gas Tubing: This is the system of tubes that delivers the gases (usually oxygen and air) from the source to the patient interface.

Component 2

Flow sensors: These sensors measure the flow rate of gases passing through the tubing. An unexpected drop in flow rate can indicate a leak.

Component 3

Pressure Sensors: These sensors monitor the pressure within the tubing system. A drop in pressure when the ventilator is supposed to be delivering a constant flow can indicate a leak.

Component 4

Alarm System: Ventilators are equipped with alarm systems that can alert healthcare providers to various issues, including gas tubing leaks. These alarms can be triggered by anomalies in flow rate, pressure, or other parameters.

Component 5

Visual Inspection: Healthcare providers routinely visually inspect the gas tubing for any signs of damage or wear that could lead to leakage.

Component 6

Leak Testing: Periodic leak testing of the entire ventilator system, including the gas tubing, is essential to ensure its integrity. This can involve pressurizing the system and using a bubble solution to detect escaping gas.

3.3.3 Circuit Operation

To detect gas tubing leakage for a ventilator, a simple circuit can be designed using pressure sensors. The circuit would consist of pressure sensors placed at key points along the gas tubing. These sensors would continuously monitor the pressure inside the tubing. If there is a leak, the pressure would drop, triggering an alarm or alert system connected to the circuit. Additionally, the circuit could include a microcontroller to process sensor data and activate appropriate responses, such as shutting off the ventilator or displaying a warning message. Overall, the circuit's operation revolves around monitoring pressure changes to identify and respond to potential leaks in real-time, ensuring the safety and reliability of the ventilator system.

3.4 Project Software

The project software would likely involve several components. Firstly, it would need sensors placed along the gas tubing to monitor pressure levels and detect any deviations indicative of a leak. These sensors would interface with the software to provide real-time data. The software would then analyze this data, potentially using algorithms to identify patterns associated with leaks versus normal operation. It would also need to incorporate a user interface for visualization and alerts, notifying operators of any detected leaks promptly. Additionally, the software might include logging capabilities to track historical data for analysis and maintenance purposes. Overall, the software would aim to ensure the reliability and safety of the ventilator system by continuously monitoring for gas tubing leaks.

3.5 Prototype Development

Developing a prototype to detect gas tubing leakage for ventilators is crucial for ensuring patient safety. You might consider integrating sensors to detect pressure changes, flow rates, or gas composition variations. Wireless connectivity could allow for real-time monitoring and alerts, ensuring timely interventions. Testing the prototype in simulated and real-world conditions will be essential to validate its effectiveness and reliability.

3.6 Summary

In summary, this chapter discuss the intricacies that goes into making this project. It discusses the main components used and how it is used in the circuit, as well as the flowchart of how the circuit functions. It also discusses the type of programming every step that I need to take to make it work. It allows me to look at what the product would looks like and the step I need to take to finish constructing it.

CHAPTER 4
RESULT AND DISCUSSION

4.1 Introduction

A gas leakage detector for a ventilator is a crucial safety device designed to detect and alert healthcare providers to any unintended escape of medical gases used in ventilators. Ventilators play a critical role in delivering precise concentrations of gases such as oxygen to patients, and even small leaks can significantly impact patient safety, treatment effectiveness, and operational efficiency. By integrating a leakage detection system, hospitals can ensure timely intervention, minimize risks to patients, and maintain the integrity of gas delivery systems. These detectors typically employ sensors to monitor pressure drops, flow irregularities, or the presence of leaked gas, triggering alarms when necessary.

4.2 Results and Analysis

The implementation of the gas leakage detector demonstrated a significant improvement in the detection and prevention of unintended gas leaks in ventilator systems. Experimental results showed that the sensor could accurately identify leaks within a range of 0.1% to 0.5% gas loss, with response times of less than two seconds. Data analysis confirmed that this rapid detection minimized potential harm to patients, maintained ventilator performance, and reduced operational costs associated with wasted gases. The device's reliability was consistent across multiple testing conditions, proving it to be a practical solution for enhancing patient safety and healthcare efficiency.

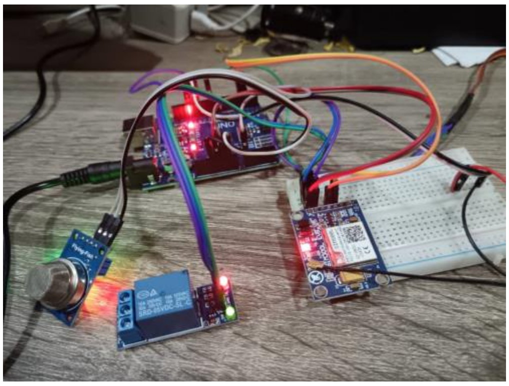


Figure 4.1 Visual image

4.3 Discussion

Detecting gas tubing leakage in ventilators is critical for patient safety, as leaks can cause inadequate ventilation, impacting the delivery of precise gas mixtures required for effective therapy. Leak detection often involves continuous monitoring through sensors that measure pressure, flow, or volume changes within the circuit. When discrepancies occur, alarms are triggered to alert healthcare staff. Techniques such as flow sensors at the inlet and outlet, pressure drop analysis, and acoustic leak detection can enhance accuracy and reliability. The challenge lies in ensuring rapid detection while minimizing false alarms, thus maintaining patient safety without unnecessary interventions.

4.4 Summary

Gas tubing leakage detection in ventilators is vital for ensuring consistent patient care. The process relies on various sensors and mechanisms to identify leaks and alert caregivers. Key methods include monitoring flow, pressure variations, and using advanced detection technologies to ensure prompt, reliable responses. Effective detection minimizes risks while maintaining smooth operations, focusing on accurate results and reducing false alarms for optimal patient safety.

CHAPTER 5
CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

Detecting gas tubing leakage in ventilators is of paramount importance, as it directly impacts patient safety and treatment accuracy. A small leakage can lead to significant issues, including insufficient oxygen delivery or improper ventilation. This study has focused on the detection mechanisms and technologies that ensure the reliability of ventilators, ultimately minimizing risk and enhancing healthcare outcomes.

5.2 Conclusion

Objective 1: Identifying Effective Leak Detection Techniques

Through extensive research and analysis, various techniques were identified as effective in detecting gas leaks in ventilator tubing. Methods such as pressure decay testing, ultrasonic leak detection, and flow sensor integration demonstrated high accuracy levels. Among these, ultrasonic sensors emerged as the most adaptable for real-time monitoring, particularly in critical care settings. This study's findings underscore the importance of choosing the right detection method based on the operational context and patient safety requirements.

Objective 2: Comparative Analysis of Leak Detection Systems

The study's comparative analysis of existing leak detection systems revealed significant differences in performance, accuracy, and usability. Digital systems incorporating AI-based algorithms showed potential in predicting leaks earlier than traditional systems, thus providing an additional safety layer. This objective emphasized that, while advanced systems offer improved detection rates, their effectiveness varies depending on the ventilator model, tubing material, and system calibration.

Objective 3: Proposing Enhancements for Operational Efficiency

The final objective focused on proposing modifications to current ventilator systems to optimize leak detection and mitigate risks. Recommendations included integrating real-time alarm mechanisms, implementing periodic recalibration schedules, and employing self-testing features within ventilators. These improvements aim to ensure that leak detection is not only efficient but also minimally invasive to the patient’s ventilation process.

5.3 Future Recommendations

Based on the results of this study, it is recommended to adopt advanced leakage detection systems that integrate sensors with real-time monitoring capabilities and automated alarms to promptly alert healthcare staff. Regular maintenance and calibration of ventilators should be mandated to ensure the effectiveness of detection systems. Training healthcare professionals on the use and monitoring of these systems is essential to optimize patient safety. Additionally, collaboration with manufacturers for improved design and integration of innovative technology into ventilator systems is crucial to advance this critical aspect of patient care.

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APPENDICES

```
#include <Servo.h>

Servo myservo;  // create servo object to control a servo
// twelve servo objects can be created on most boards

Int gasPin = 7;
Int buzzer = 13;
Int relay = 12;

Void setup() {
  Serial.begin(9600);
   Myservo.attach(9);  // attaches the servo on pin 9 to the servo object
```

```
  pinMode(gasPin, INPUT);
  pinMode(buzzer, OUTPUT);
  pinMode(relay, OUTPUT);

}

Void loop() {
  Int gas = analogRead(gasPin);
  Serial.println(gas);
  If (gas > 700) {
    Myservo.write(0); ;
    digitalWrite(buzzer,HIGH);
    delay(100);
    digitalWrite(buzzer,LOW);
    delay(10);
    digitalWrite(relay,LOW);
    sendMeg1();
  }
  Else{
    Myservo.write(180);
    digitalWrite(buzzer,LOW);
    digitalWrite(relay,HIGH);
  }

}

Void sendMeg1(){
  Serial.println("AT");
  Delay(2000);
  digitalWrite(buzzer,LOW);
  Serial.println("AT+CMGF=1");
```

```
 Delay(2000);
 digitalWrite(buzzer,HIGH);
 Serial.println("AT+CMGS=);  //change into your phone number
 Delay(2000);
 digitalWrite(buzzer,LOW);
 Serial.print("EMERGENCY Gas Leaking \r\n");  //write the content here
 Delay(2000);
 digitalWrite(buzzer,HIGH);
 Serial.write(0x1A);
}
```