Wireless Fire Alarm System

Submitted in partial fulfillment of the requirements

of the degree of

Bachelor of Electronics Engineering

by

Siddhant Dethe (Roll No. 20103B0048)
Shreyas Tukrul (Roll No. 20103B0051)
Tejas Brid (Roll No. 20103B0031)
Navdeep Patil (Roll No. 20103B0049)

Supervisor:

Prof. Amol Sakhalkar

University of Mumbai

Department of Electronics Engineering

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CERTIFICATE

This is to certify that the project entitled **“Wireless Fire Alarm System”** is a bonafide work of “**Siddhant Dethe” (Roll No. 20103B0048), “Shreyas Tukrul (Roll No. 20103B0051), “Tejas Brid” (Roll No. 20103B0031), “Navdeep Patil (Roll No. 20103B0049)”** submitted to the University of Mumbai in partial fulfillment of the requirement for the award of the degree of **“Undergraduate** in **“Bachelors of Electronics Engineering”**.

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Thesis Approval for Project Report for B. E.

This project report entitled ***Wireless Fire Alarm System*** by ***Siddhant Dethe, Shreyas Tukrul, Tejas Brid, Navdeep Patil*** is approved for the degree of **Bachelors of Electronics Engineering**.

Examiners

1.______________________________

2.______________________________

Date:

Place:

Declaration

We declare that this written submission represents our ideas in our own words and where others' ideas or words have been included, we have adequately citedand referenced the original sources. We also declare that we have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in our submission. We understand that any violation of the above will be cause for disciplinary actionby the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been takenwhen needed.

Date:

Sign:
Siddhant Dethe (Roll No. 20103B0048)
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Acknowledgement

In successfully completing our project, we are indeed thankful to many people who have encouraged & helped us in a variety of ways. It is a privilege to express our gratitude to the people involved. Our profound & heartfelt thanks to Prof. Amol Sakhalkar who consented to be our project guide. We would like to thank our guide for encouraging us, giving his valuable guidance & making us reimagine the broader spectrum of our project & its applications. We would also like to thank the Project Head of Final year in Electronics department, Prof. Akhil Masurkar & the Head of the Department Prof. Dr. Arun Chavan for giving us the necessary support & opportunity in completing & presenting the project.

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Abstract

This concept proposes a real-time fire safety system that uses wireless communication to improve fire detection and notification. The system's central processing unit is an Arduino Uno microcontroller, which communicates with an NRF24L01+ module via wireless data transmission. The MQ-2 smoke sensor module detects smoke particles and sends a vital signal. A TP4056 module provides efficient battery management for the system's operation.
The Arduino Uno interprets smoke sensor data and sounds an alert when it exceeds a predetermined smoke threshold. The alarm signal is then wirelessly delivered via the NRF24L01+ module, allowing for distant notification and a speedier reaction time in case of a fire emergency.

Keywords:

Wireless Fire Alarm with Arduino Uno, NRF24L01, MQ-2 Smoke Sensor

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Chapter 01

Introduction

Fire, a ubiquitous energy with both constructive and destructive potential, has had a tremendous impact on human history. While fire offered warmth, light, and safety in ancient civilizations, its uncontrolled nature poses an ongoing threat to life and well-being. According to the National Fire Protection Association (NFPA), fires in the United States alone resulted in 339,300 civilian injuries and 3,575 civilian deaths in 2021 [1]. These numbers highlight the crucial need for effective fire safety measures to protect lives and livelihoods.

Fire safety encompasses a holistic approach that involves fire prevention, suppression, and education. Traditional methods rely on smoke detectors, sprinkler systems, and public awareness campaigns. However, the ever-evolving technological landscape is paving the way for more sophisticated and interconnected fire safety solutions. The emergence of the Internet of Things (IoT) has facilitated the development of smart fire alarm systems that leverage wireless communication protocols and sensor networks, offering enhanced functionality and improved situational awareness [2]. Aside from the immediate fear of casualties, fires can have terrible social and economic consequences. Uncontrolled fires can cause extensive property damage, displacing families from their homes and damaging businesses. Survivors of fires may experience long-term psychological stress [3]. Furthermore, fires cause enormous environmental damage by emitting chemicals and destroying ecosystems [5]. Early detection is critical for reducing the degree of fire damage and loss of life. Interconnected fire alarm systems allow for faster reaction times, which can considerably improve fire safety outcomes. Conventional fire alarm technology, such as smoke and heat detectors, are essential. However, they frequently rely on wired connections, which reduces their range and versatility. Furthermore, single points of failure can disable entire systems [5,6]. Emerging technologies are continuously challenging the boundaries of fire safety. The Internet of Things (IoT) and wireless sensor networks present a significant opportunity for the creation of intelligent, interconnected fire alarm systems. Specifically, nRF (Nordic Radio Frequency) modules are gaining interest because to their low-power consumption, short-range secure communication, and ease of deployment. [7,8]

Our project of Wireless Fire Safety Alarm transmits the signal wirelessly with the aid of nRF module thereby reducing the risks involved in physical detection of fire, wire cutting & time consumption.

Chapter 02

Literature Survey

Fire safety is a top priority in both residential and commercial settings. Traditional fire alarm systems, while effective, frequently rely on wired connections, which limits their adaptability and scalability. This implies investigating alternative options based on developments in wireless communication technologies.

Several research projects have focused on building wireless fire alarm systems that use a variety of communication protocols. Lee et al. (2014) suggested a smart house fire alarm system based on ZigBee communication, a low-power, short-range wireless technology appropriate for home automation applications [2]. Their solution provided real-time fire detection and remote monitoring capabilities. However, ZigBee networks are sensitive to interference from other wireless devices running in the same frequency range. Shafiq et al. (2018) introduced a wireless fire alarm system based on the ESP8266 microcontroller and ThingSpeak cloud platform [8]. This system provided remote monitoring and notification capabilities, but it was dependent on an internet connection, which could jeopardize reliability if the internet went down. The Internet of Things (IoT) has emerged as a promising model for creating networked fire protection solutions. IoT-based fire alarm systems use sensor networks to gather real-time information on temperature, smoke, and other fire signs. This data can then be wirelessly transferred to a central hub for analysis and alarm activation. Dwivedi et al. (2019) investigated the use of IoT in fire safety, emphasizing its ability to increase response times and situational awareness during fire situations [9]. However, security concerns about networked devices and potential weaknesses in data transmission must be carefully considered. Among the several wireless communication protocols suited for IoT-based fire alarm systems, nRF (Nordic Radio Frequency) modules are notable for their low power consumption, short-range secure connection, and ease of deployment [7]. Nordic Semiconductor (n.d.) emphasizes the versatility and security aspects of nRF modules, which make them ideal for resource-constrained fire alarm sensor networks [10].

While nRF technology has promising benefits, its restricted range may demand the usage of mesh networking approaches in bigger deployments. More study, as investigated by Ali et al. (2019), is required to improve network topologies and communication protocols for maximizing reliability and scalability in nRF-based fire alarm systems [11]. Any fire alarm system's efficiency is determined on its accuracy and reliability. Wu et al. (2020) underline the necessity of thorough testing and performance review to ensure appropriate fire event detection while minimizing false alarms [3]. Furthermore, integration with existing fire safety infrastructure, as investigated by Kim et al. (2018), can improve the overall effectiveness of wireless fire alarm systems [4]. Wireless technologies, particularly nRF modules, present exciting opportunities for creating integrated and scalable solutions. However, security, network optimization, and system integration remain critical factors in maintaining the dependability and effectiveness of nRF-based fire alarm systems.

Chapter 03

Objectives

1. **Reliable Fire Detection**
   To create and build a system for accurately detecting fire incidents utilizing appropriate sensors such as temperature sensors and smoke detectors.

2. **Wireless Communication**
   To create a dependable wireless network between fire sensors and a central hub by utilizing nRF modules for data transfer.

3. **Triggering Fast Alarms**
   To reduce response time by guaranteeing effective data processing and prompt alarm activation at the central hub upon fire detection.

4. **Enhancing Situational Awareness**
   To create features that offer real-time information on fire location and severity, potentially integrating with existing building management systems.

5. **Low Power Consumption**
   To optimize system design to reduce the power consumption of nRF modules and fire sensors, assuring longer battery life.

6. **Scalability & Expandability**
   To design the system with modularity in mind, enabling for easy extension and the addition of more sensors to cover greater areas.

7. **Cost Effectiveness**
   To use cost-effective components and nRF modules to design a fire alarm system that is both accessible and economical for a variety of deployment scenarios.

Chapter 04

Project Development

The hardware section of the project is the integration of various circuits controlled by Arduino Uno. Table 4.1 provides the entire list of hardware components used for the project.

Table 4.1 Hardware components

Hardware components
Microcontroller – Arduino Uno
NRF24LO1
Small Buzzer
Li ion batteries
TP4056
MQ2 Smoke Sensor Module
16x2 LCD Display with I2C interface – Blue

Hardware Components:

4.1. Microcontroller – Arduino Uno

Arduino Uno is a microcontroller board built around the 8-bit ATmega328P microcontroller. In addition to the ATmega328P, it contains other components like as a crystal oscillator, serial communication, voltage regulator, and so on to support the microcontroller. The Arduino Uno contains 14 digital input/output pins (6 of which can be used as PWM outputs), 6 analog input pins, a USB connection, a power barrel connector, an ICSP header, and a reset button. ATmega328P microcontroller supports UART TTL (5V) serial communication via digital pins 0 (Rx) and 1 (Tx). An ATmega16U2 on the board channels serial communication over USB, appearing as a virtual com port to computer software. The ATmega16U2 firmware makes use of common USB COM drivers and does not require an extra driver. [12]

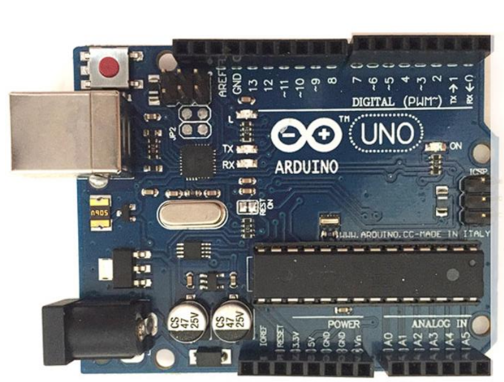

Fig 4.1.1 Arduino Uno

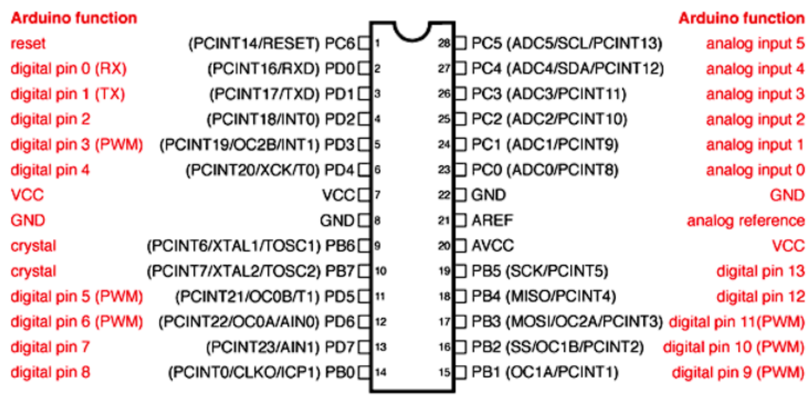

Fig 4.1.2 Pin Diagram (Arduino Uno)

Features:

- Atmega328P Microcontroller:

    1. High-performance, low-power 8-bit processor.
    2. Achieve up to 16 MIPS at 16 MHz clock frequency.
    3. 32 kB, 2 KB used by the bootloader.
    4. 2 kB internal SRAM, 1 kB EEPROM
    5. 32 × 8 General Purpose Working Registers
    6. Real-time counter with separate oscillator
    7. Six PWM channels.
    8. Programmable Serial USART with Master/Slave SPI Serial Interface.

- I/O:

    1. 14 Digital

    2. 6 Analog

    3. 6 PWM Output

4.2. NRF24LO1

The nRF24L01 module is a wireless transceiver, which means it can send and receive data. They operate at 2.4GHz, which falls within the ISM band and hence is acceptable to use in practically all nations for technical applications. When run efficiently, the modules may span 100 meters (200 feet), making them ideal for any wireless remote-controlled applications. The module works at 3.3V, making it compatible with both 3.2V and 5V systems. Each module has a 125-bit address range and may connect with up to six additional modules, allowing several wireless units to communicate in the same area. Hence mesh networks, or other types of networks are possible using this module. [13]

Pinout Configuration:

Table 4.2 Pinout Configurations (nRF Module)

Pin Number	Pin Name	Abbreviation	Function
1	Ground	Ground	Connected to the Ground of the system
2	Vcc	Power	Powers the module using 3.3V
3	CE	Chip Enable	Used to enable SPI communication
4	CSN	Ship Select Not	This pin has to be kept high always; else it will disable the SPI
5	SCK	Serial Clock	Provides the clock pulse using which the SPI communication works
6	MOSI	Master Out Slave In	Connected to MOSI pin of MCU, for the module to receive data from the MCU
7	MISO	Master In Slave Out	Connected to MISO pin of MCU, for the module to send data from the MCU
8	IRQ	Interrupt	It is an active low pin and is used only if interrupt is required

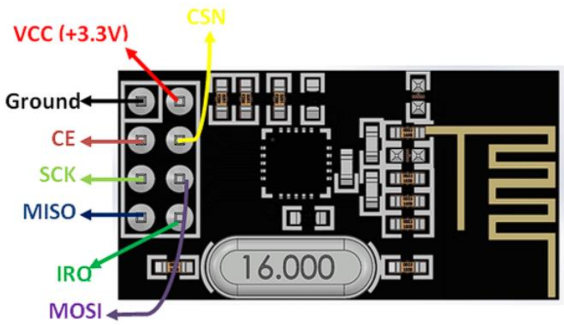

Fig 4.2 nRF Module

Features:

- 2.4GHz RF Transceiver Module
- Operating voltage: 3.3 volts.
- Nominal current: 50 mA
- Range: 50 to 200 ft.
- Operating current: 250 mA (max)
- Communication Protocol: SPI.
- Baud Rate: 250 kbps – 2 Mbps.
- Channel Range: 125.
- Maximum Pipelines per node: 6
- A low-cost wireless solution

4.3. TP4056:

The TP4056 is a comprehensive linear charger for single-cell lithium-ion batteries that provides consistent current and voltage. The TP4056's SOP packaging and low external component count make it excellent for portable applications. Furthermore, the TP4056 is compatible with both USB and wall adapters. The integrated PMOSFET construction eliminates the need for a blocking diode and prevents a negative charge current circuit. Thermal feedback modulates charge current to keep the die from overheating during high power operation or high ambient temperatures. The charge voltage is fixed at 4.2V, and the charge current can be controlled externally using a single resistor. After reaching the final float voltage, the TP4056 automatically terminates the charge cycle when the charge current reduces to 1/10th of the specified value. [14]

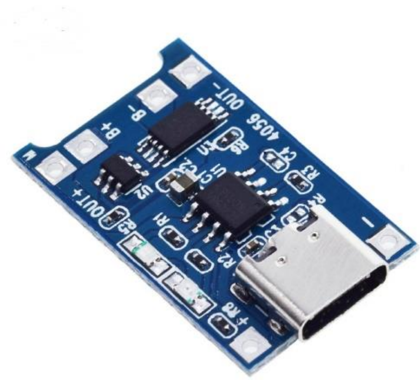

Fig 4.3. TP4056

Features:

- Programmable charge current up to 1000mA
- No MOSFET, sense resistor, or blocking diode required.
- Complete linear charger in SOP-8 packages for single-cell lithium-ion batteries.
- Constant-Current/Constant-Voltage
- Charges single-cell lithium-ion batteries directly via USB port.
- Preset 4.2V charging voltage with 1.5% accuracy.
- Automatic Recharge
- Two Charge Status Output Pins
- C-10 Charge Termination
- Soft start limits the inrush current.

4.4. MQ2 Smoke Sensor Module:

Fig 4.4. MQ2 Smoke Sensor Module

Table 4.4.1 MQ2 Smoke Sensor Module Pin Configuration

Pin Number	Pin Name	Description
1	Vcc	This pin powers the module, typically the operating voltage is +5V
2	Ground	Used to connect the module to system ground
3	Digital Out	To digital output from this pin, by setting a threshold value using the potentiometer.

Table 4.4.2 MQ2 Sensor Pin Configuration

Pin Number	Pin Name	Description
1	H -Pins	Out of the two H pins, one pin is connected to supply and the other to ground
2	A-Pins	The A pins and B pins are interchangeable. These pins will be tied to the Supply voltage.
3	B-Pins	The A pins and B pins are interchangeable. One pin will act as output while the other will be pulled to ground.

Chapter 05

Methodology

The presented code establishes wireless connectivity between several devices using the Arduino Uno and NRF24L01 radio modules. The code is divided into three portions, each of which serves a different purpose:

1. Sending data from one Arduino to another
2. Receiving and forwarding data
3. Displaying received data on an LCD screen.

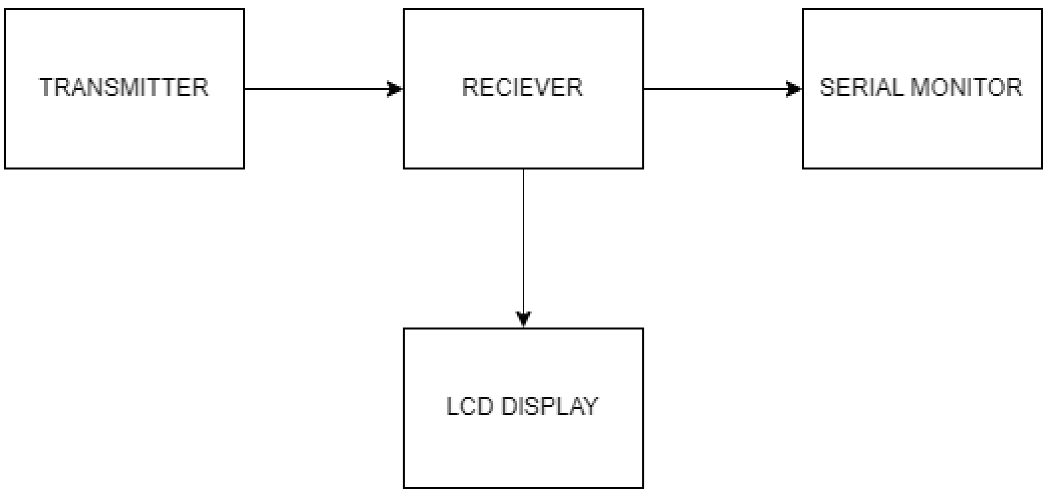

Fig 5.1. Block Diagram (Wireless Fire Alarm System)

5.1. Transmitter:

This code sets a specific communication address for the NRF24L01 radio module. It then sends the "Fire in M Block" message over the radio at two-second intervals. Given below is a flow of the Transmitter sketch:

A. Setup Function:

- Initializes the radio module.
- Sets the communication address.
- Reduces the power level to a minimum.
- Stops listening for new communications.

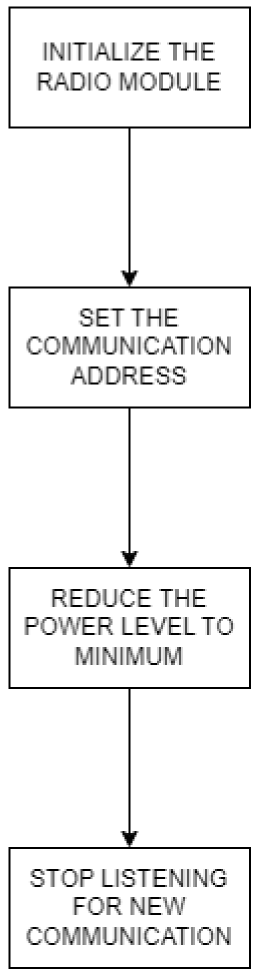

Fig 5.2 Transmitter Setup Function

B. Loop Function:

- Defines the message "Fire in M Block".
- Sends the message using the radio module.
- Delays 2 seconds before repeating.

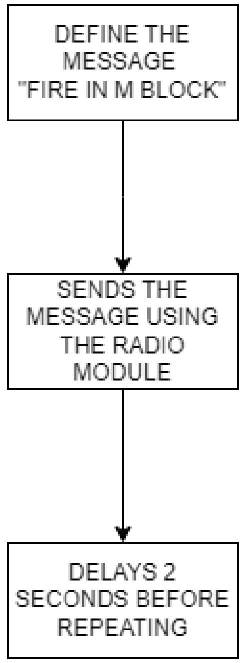

Fig 5.3 Transmitter Loop Function

5.2. Relay:

This code configures another Arduino to accept data from the transmitter at the provided address. When data is received, it forwards it to another address, thus serving as a relay. Given below is a flow of the Relay sketch:

A. Setup Function:

- Initializes the radio module.
- Sets the communication address and starts listening for incoming messages.

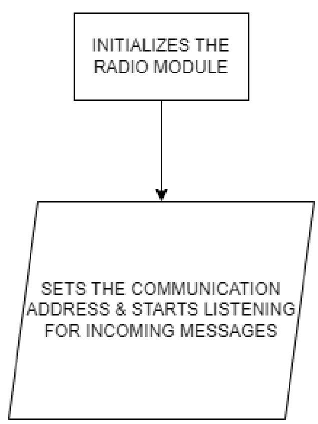

Fig 5.4 Relay Setup Function

B. Loop Function:

- Determines whether there are any available messages.
- If the message is available:
  - Reads the message.
  - Prints the message to the serial monitor.
  - Stops listening.
  - Changes the transmission address to the receiver's address.
  - Sends the message to the recipient.
  - Resumes listening.

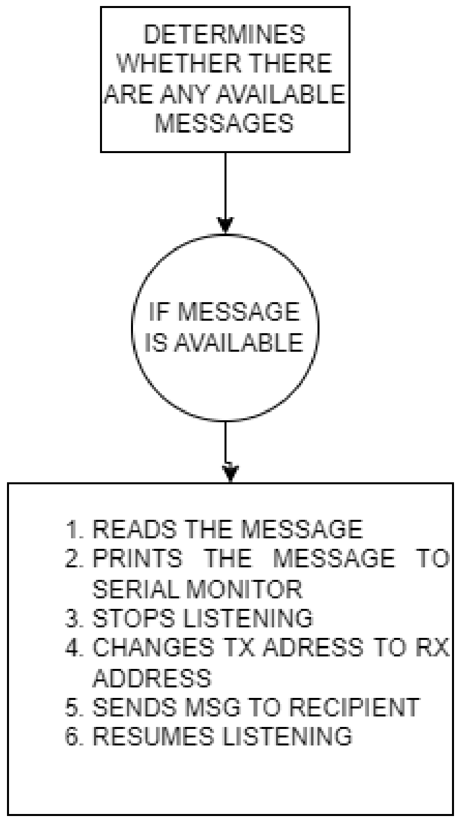

Fig 5.5 Relay Loop Function

5.3. Receiver:

This code sets up an LCD screen and shows the data received from the specified address on it. This sketch configures an NRF24L01 module as a receiver. It listens for messages from the relay and displays them on an LCD screen. Given below is a flow of the Receiver sketch:

A. Setup Function:

- Initializes the radio module.
- Sets the communication address and starts listening for incoming messages.
- The LCD panel is set to its initial state.

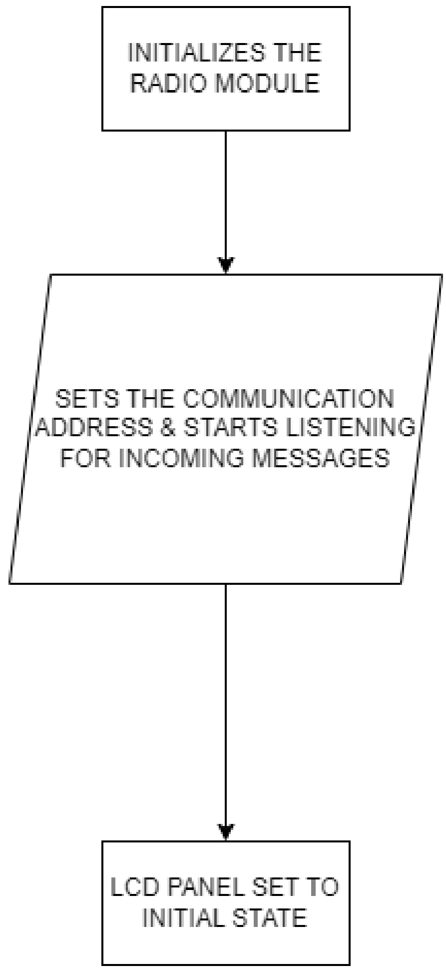

Fig 5.6 Receiver Setup Function

B. Loop Function:

- Determines whether there are any available messages.
- If the message is available:
- Reads the message.
- Prints the message to the serial monitor.
- Shows the message on the LCD panel.

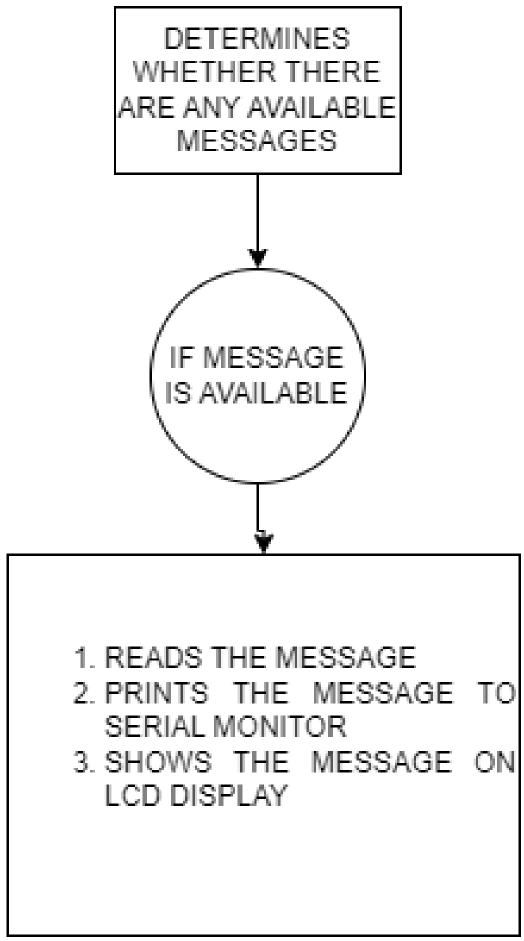

Fig 5.7. Receiver Loop Function

Chapter 06

Results

Fig 6.1 shows the control panel featuring “Fire in M Block” message. Fig 6.2 shows the hopper node. Fig 6.3 shows the smoke detector node.

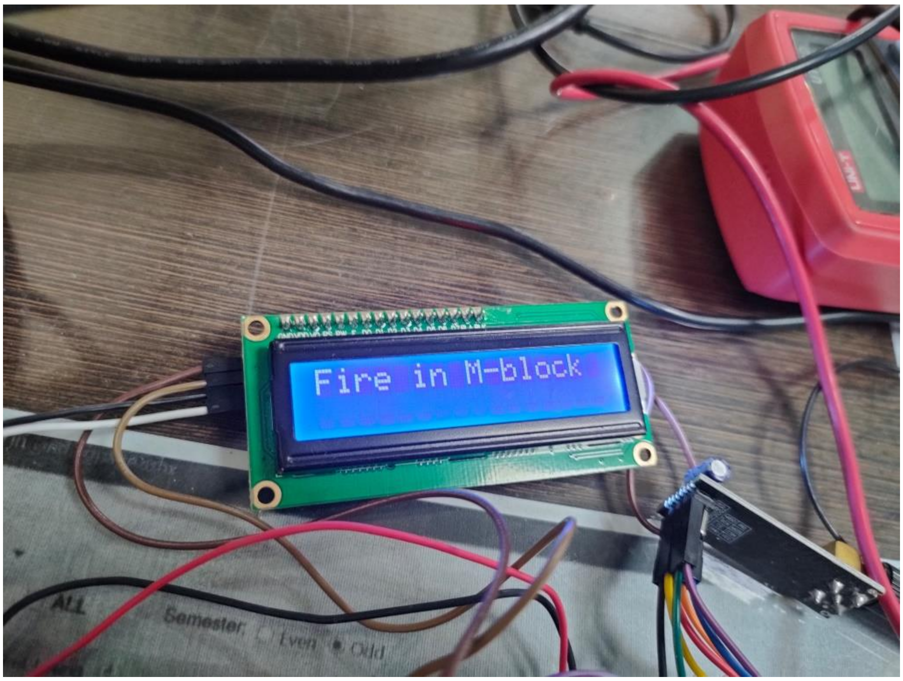

Fig 6.1: Control Panel

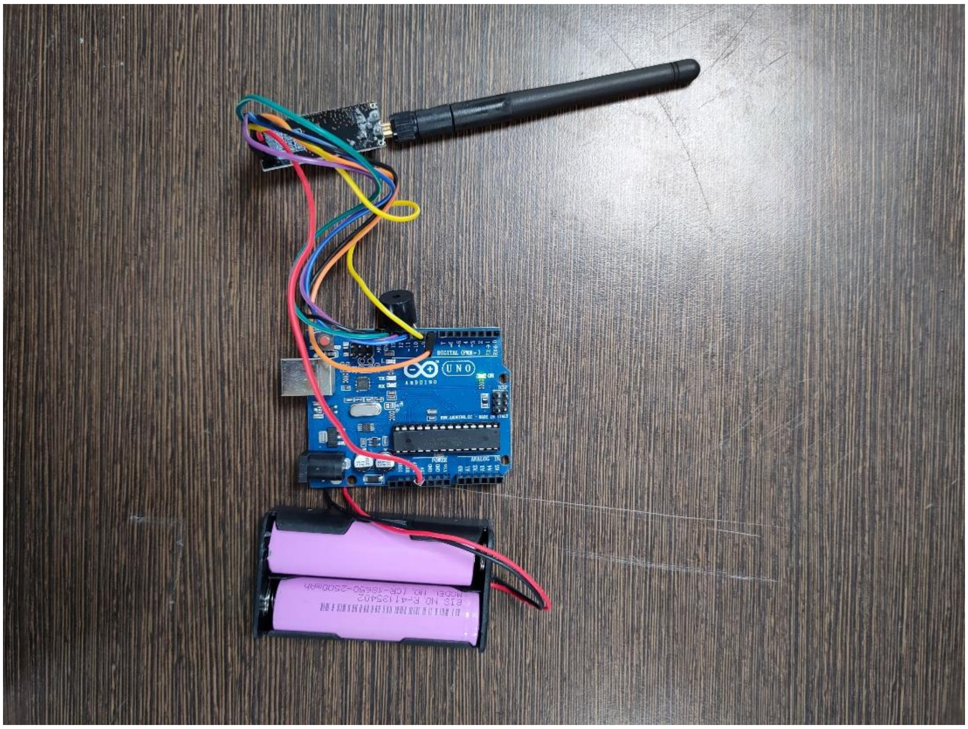

Fig 6.2 Hopper Node

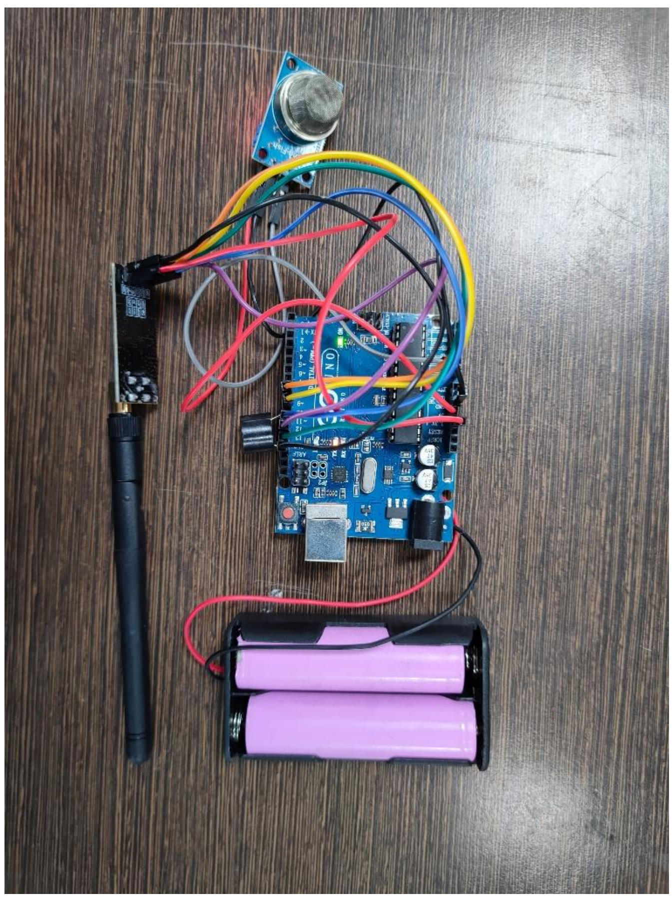

Fig 6.3 Smoke Detector Node

Chapter 07

Cost Analysis

Sr. No.	Component	No. of Units	Cost (INR)
1.	Arduino Uno	5	2100
2.	NRF24LO1 with antenna	5	725
3.	Small Buzzer	5	75
4.	Li ion batteries	10	750
5.	TP4056	1	45
6.	Double battery sockets	5	150
7.	Uno programming cable	2	80
8.	Female – Male Jumper wires	25	200
9.	MQ2 Smoke Sensor Module	2	160
10.	16 x 2 LCD Display with I2C interface - Blue	1	100
11.	Total		4,385

Chapter 08

Future Scope

1. Improved detection and reliability:

- **Multiple Sensor Integration:-**
  Integrate smoke (MQ-2), heat (thermistor), and CO (MQ-7) sensors for a more comprehensive fire detection solution. This lowers false alarms from cooking smoke while accurately identifying combustion byproducts.

- **Advanced Sensor Algorithms:-**
  Use machine learning or fuzzy logic-based algorithms on the Arduino to analyze sensor data in real time, resulting in better fire pattern detection and lower false positives. This may include techniques such as anomaly detection or time-series analysis.

2. Advanced Communications and Networking:

- **Mesh Networking:**
  The NRF24L01 supports mesh networking protocols for self-healing and scalable communication. This establishes a network in which each node can relay messages, ensuring that data reaches the central hub even when some nodes are compromised or out of range. Consider the "RF24Mesh" library for Arduino.

- **Cellular or LoRaWAN Connectivity:**
  Integrate cellular modules (e.g., SIM800L) or LoRaWAN transceivers for long-distance, dependable communication with a central monitoring station or emergency services, avoiding probable local network disturbances.

- **Two-Way Communication:**
  Enable two-way communication between nodes for functionality such as sprinkler system remote activation, door unlocking, and alerting specified devices (e.g., cellphones).

Chapter 9

Conclusion

This project showcases a wireless fire safety system based on the Arduino Uno microcontroller, the NRF24L01 radio module, the TP4056 battery charger, and the MQ-2 smoke sensor module. The central processing unit is the Arduino Uno, which reads data from the smoke sensor and sounds an alert if a fire is detected. The NRF24L01 allows for wireless communication across numerous systems, resulting in a scalable network of sensors across a building or complex.

The TP4056 keeps the system operable by controlling battery charging over extended use. This design provides various advantages. Wireless communication reduces the need for intricate wiring, resulting in faster installation and more adaptability to existing structures. The modular architecture enables for easy extension by adding more sensor nodes outfitted with the Arduino Uno, NRF24L01, and MQ-2 combo. This generates a comprehensive fire detection network that provides better coverage than a single sensor system. While the MQ-2 sensor is a dependable smoke detector, it's crucial to recognize its limits. It may not be sensitive enough to detect all types of fire, and false alarms can arise as a result of dust or cooking smells. Consider adding additional sensor types, such as heat detectors, in addition to the smoke sensor, to improve safety.

Overall, this research demonstrates a cost-effective and customizable fire safety system with wireless communication capabilities. By combining easily available components and the power of Arduino programming, this design provides a useful fire safety solution for a variety of applications. Remember, this is a prototype that needs be thoroughly tested and refined before full-scale implementation.

Chapter 10

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