RFID BASED PETROL PUMP AUTOMATION SYSTEM

A Mini Project Report

Submitted by

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in

ELECTRONICS AND COMMUNICATION ENGINEERING

Under the guidance of

DR. SINDHU S.

JYOTHI ENGINEERING COLLEGE
LEAD KINDLY LIGHT
CREATING TECHNOLOGY LEADERS OF TOMORROW
ESTD 2002

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

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May 2024

DECLARATION

We the undersigned hereby declare that the project report " RFID Based Petrol Pump Automation System", submitted for partial fulfillment of the requirements for the award of degree of Bachelor of Technology of the APJ Abdul Kalam Technological University, Kerala is a bonafide work done by us under supervision of Dr. Sindhu S. This submission represents our ideas in our own words and where ideas or words of others have been included, we have adequately and accurately cited and referenced the original sources. We also declare that we have adhered to ethics of academic honesty and integrity and have not misrepresented or fabricated any data or idea or fact or source in this submission. We understand that any violation of the above will be a cause for disciplinary action by the institute and/or the University and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been obtained. This report has not been previously used by anybody as a basis for the award of any degree, diploma or similar title of any other University.

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CREATING TECHNOLOGY LEADERS OF TOMORROW
ESTD 2002

CERTIFICATE

This is to certify that the report entitled " **RFID BASED PETROL PUMP AUTOMATION SYSTEM** " submitted by AISWARIYA R. (JEC21EC005), PRANAV PRASAD (JEC21EC030), VIVEK.M (JEC21EC036), JINO JOSEPH (LJEC21EC041) to the APJ Abdul Kalam Technological University in partial fulfillment of the requirements for the award of the Degree in Bachelor of Technology in **ELECTRONICS AND COMMUNICATION ENGINEERING** is a bonafide record of the mini project work carried out by them under my/our guidance and supervision. This report in any form has not been submitted to any other University or Institute for any purpose.

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Head of the Department

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VISION OF THE INSTITUTE

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PROGRAMME EDUCATIONAL OBJECTIVES

PEO 1: Graduates shall have fundamental and advanced knowledge in Electronics and Communication Engineering along with knowledge in mathematics,science, and computing and get employed in national or international organizations or government agencies.

PEO 2: Graduates shall have ability in analyzing, designing, and creating innovative solutions which lead to a life long learning process or higher qualification, making them experts in their profession thus helping to solve Electronics and Communication Engineering and social problems.

PEO 3: Graduates shall have good organizing capability, presentation skills, communicating ability, leadership, teamwork, and ethical practices.

PROGRAMME SPECIFIC OUTCOMES

Graduate possess -

PSO 1: Professional skills: Associate the concepts related to Electronics, Communication, Embedded Systems, Signal Processing and VLSI to solve real life problems.

PSO 2: Problem solving ability: Comprehend technology advancement to analyze and design systems using modern design tools for the benefit of the society

PSO 3: Lifelong learning and ethical Values: Students should be able to develop communication skills, work as a team, develop leadership qualities, become professionals or entrepreneurs with ethical values

PROGRAMME OUTCOMES

1. **Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
2. **Problem analysis:** Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
3. **Design/development of solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
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11. **Project management and finance:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
12. **Life-long learning:** Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

COURSE OUTCOMES

COs	Description	Bloom's taxonomy level
CO1	Be able to practice acquired knowledge within the selected area of technology for project development.	Applying(P),Understanding(U),Remembering(R)
CO2	Identify, discuss and justify the technical aspects and design aspects of the project with a systematic approach.	Understanding(U),Analyzing(A)
CO3	Reproduce, improve and refine technical aspects for engineering projects.	Applying(P),Evaluate(E),Create(C)
CO4	Work as a team in development of technical projects.	Evaluate(E),Analyzing(A)
CO5	Communicate and report effectively project related activities and findings.	Applying(P),Analyzing(A)

CO MAPPING TO POs

	POs														
COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	2	2	3				1		2	2	3	1
CO2	3	3	3	2	2	3				1		2	2	2	1
CO3	3	3	3	2	2	3				1	1	2	2	3	1
CO4								3	3	3	3	2			3
CO5								3	3	3	1	2			3

CO MAPPING TO PSOs

	PSOs		
COs	PSO1	PSO2	PSO3
CO1	2	3	1
CO2	2	2	1
CO3	2	3	1
CO4			3
CO5			3

ABSTRACT

Outlining a proposal for an advanced automation system for petrol pumps, the document highlights the integration of RFID technology for enhanced security and efficiency. The system incorporates RFID authentication, keypad input, and cutting-edge sensor technology, ensuring safe and precise fuel dispensing operations.

At the core of the system is an ESP32 WROOM32 DEV KIT, complemented by an RFID reader module, keypad, LCD display, DC motor pump, and various sensors aimed at optimizing safety, efficiency, and monitoring capabilities. Users authenticate themselves via RFID tags, facilitating secure transactions and accurate input of desired fuel quantities. Real-time monitoring of fuel levels and flow rates guarantees precise dispensing, providing immediate feedback and control over the process.

Supporting remote operation, the system allows for flexible and efficient fuel pump management. Energy efficiency is enhanced through the optimized control of dispensing mechanisms. By incorporating these advanced features, the proposed system offers a comprehensive, efficient, and modern solution for petrol stations, significantly improving the overall fuel dispensing experience for both operators and customers.

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LIST OF ABBREVATIONS

API	Application Programming Interface
DC	Direct Current
ECE	Electronics & Communication Engineering
ESP32	Espressif 32 module
GPIO	General Purpose Input / Output
GSM	Global system for Mobile communication
I2C	Inter-Integrated Circuit
IDE	Integrated Development Environment
IoT	Internet of Things
JECC	Jyothi Engineering College, Cheruthuruthy
LCD	Liquid crystal display
MISO	Master Input Slave Output
MOSI	Master Out Slave In
RC522	Reader Chip 522
RFID	Radio Frequency Identification
SCL	Serial Clock Line
SDA	Serial Data Line
SoC	System On Chip
SPI	Special Peripheral Interface
UART	Universal Asynchronous Receiver-Transmitter
UID	Unique Identifier
USB	Universal Serial Bus
Wi-Fi	Wireless Fidelity

CHAPTER 1

INTRODUCTION

1.1 Overview

In an era defined by rapid technological advancement and evolving consumer expectations, the RFID-based petrol pump automation system emerges as a beacon of innovation and efficiency, poised to revolutionize the fuel dispensing landscape across diverse sectors and scenarios. As traditional petrol pump operations grapple with challenges related to manual authentication, inefficient transaction processing, and limited data visibility, the need for a comprehensive, automated solution has never been more pronounced

The RFID-based petrol pump automation system addresses these challenges head-on, offering a multifaceted approach to fuel management that transcends traditional boundaries and unlocks new opportunities for operational excellence and customer satisfaction. From bustling urban petrol stations to remote rural outposts, the system's versatility and adaptability make it a cornerstone of future development in the fuel dispensing industry. In urban environments, where congestion, long queues, and high transaction volumes are commonplace, the RFID-based system offers a lifeline for petrol pump operators seeking to enhance efficiency and customer throughput. By automating user authentication, vehicle identification, and payment processing, the system streamlines the entire fuel dispensing process, reducing waiting times, minimizing errors, and improving overall service quality. Moreover, the system's real-time monitoring capabilities provide invaluable insights into fuel inventory levels, enabling operators to optimize replenishment schedules, prevent stockouts, and maintain uninterrupted service.

In remote or off-grid locations, where access to fuel is limited and logistics present significant challenges, the RFID-based system serves as a catalyst for empowerment and sustainability. By enabling unmanned or minimally staffed petrol stations, the system extends the reach of fuel distribution networks, bringing essential services to underserved communities and facilitating economic development. Additionally, the system's remote monitoring and control capabilities allow operators to oversee operations from afar, ensuring compliance with safety standards, detecting anomalies, and responding to emergencies in real-time.

Beyond the traditional realm of petrol pump operations, the RFID-based system finds applications in a myriad of industries and scenarios, from fleet management and logistics to agriculture and construction. In fleet management, for example, the system enables precise tracking of fuel consumption for individual vehicles, facilitating cost allocation, route optimization, and preventive maintenance. In agriculture, the system can be integrated into refueling stations for farm machinery, Providing farmers with accurate data on fuel usage, operational efficiency, and crop yield. The advantages of the RFID-based petrol pump automation system are manifold. By automating manual processes and enhancing data visibility, the system improves operational efficiency, reduces labor costs, and minimizes the risk of errors and fraud. Additionally, the system promotes sustainability by optimizing fuel consumption, reducing emissions, and enhancing resource utilization. From a customer perspective, the system enhances convenience, speeds up transaction times, and enhances safety and security.

In essence, the RFID-based petrol pump automation system represents a paradigm shift in fuel management, offering a holistic solution that addresses the diverse needs and challenges of modern-day petrol pump operations. As industries continue to embrace automation, connectivity, and data-driven decision-making, the system stands poised to drive innovation, foster growth, and shape the future of fuel dispensing worldwide.

1.2 Motivation behind this work

The RFID-based petrol pump automation system represents a pivotal advancement in the realm of fuel dispensing technology, driven by the imperative need to modernize and optimize conventional petrol pump operations. Traditional fueling stations have long relied on manual processes, rudimentary authentication methods, and outdated equipment, leading to inefficiencies, errors, and security vulnerabilities. In today's rapidly evolving landscape, characterized by escalating consumer demands, stringent regulatory requirements, and technological innovation, the need for a paradigm shift in fuel dispensing practices has never been more pronounced.

At the heart of this project lies the recognition of the myriad challenges plaguing conventional petrol pump operations and the unwavering commitment to overcome them through innovative solutions. Foremost among these challenges is the inefficiency inherent in manual processes, which not only consume valuable time and resources but also increase the risk of errors and discrepancies. From manually inputting transaction details to physically monitoring fuel levels and inventory, the reliance on manual labor leaves petrol pump operators susceptible to human error, delays, and operational inefficiencies. Moreover, the prevailing security concerns surrounding traditional authentication methods, such as cash transactions and card swiping, necessitate a more robust and foolproof approach to user authentication and transaction processing. Instances of fraud, identity theft, and unauthorized access underscore the vulnerabilities inherent in legacy systems, highlighting the urgent need for enhanced security measures and authentication protocols.

Furthermore, the emergence of new consumer trends and expectations, driven by advancements in technology and changing market dynamics, underscores the need for petrol pump operators to adapt and innovate to remain competitive.

Today's consumers demand speed, convenience, and reliability in their fueling experience, expecting seamless transactions, personalized services, and enhanced safety measures. Addressing these evolving consumer demands requires a holistic approach that leverages cutting-edge technologies, such as ESP32 (ESP32-based microcontroller), IoT (Internet of Things), and automation.

Against this backdrop, the RFID-based petrol pump automation system emerges as a beacon of innovation and progress, offering a transformative solution that redefines the fueling experience for operators and consumers alike. By harnessing the power of RFID technology, the system revolutionizes key aspects of petrol pump operations, from user authentication and transaction processing to inventory management and security. Through the seamless integration of RFID tags, readers, and sensors, the system enables swift and secure identification of vehicles, automated fuel dispensing, and real-time monitoring of fuel levels and transactions. Moreover, the adoption of RFID technology opens up a myriad of possibilities for future development and expansion, ranging from enhanced data analytics and predictive maintenance to integration with other IoT devices and platforms. By embracing RFID-based automation, petrol pump operators can unlock new levels of efficiency, accuracy, and transparency in their operations, positioning themselves at the forefront of innovation and differentiation in the competitive fueling market.

1.3 Report outline

This report consists of six chapters. The first chapter is the introduction of the project which provides an overview and motivation behind this work. This details the importance of RFID-based petrol pump automation system in the modern scenario. The second chapter is the literature survey of existing systems. The third chapter deals with the methodology which includes the block diagram and circuit diagram. The fourth chapter is the system design comprises hardware and software used. The fifth chapter is product development. The last chapter discusses the conclusion and future scope.

CHAPTER 2

LITERATURE SURVEY

2.1 Introduction

The integration of Radio Frequency Identification (RFID) and Internet of Things (IoT) technologies has emerged as a transformative force in the realm of petrol pump operations management. This literature survey delves into the existing research landscape, exploring advancements, challenges, and innovations within this domain.

The reviewed literature underscores the critical role of RFID in automating inventory management, enhancing operational efficiency, and improving overall service delivery at petrol pumps. IoT complements these capabilities by enabling real-time data analytics, facilitating proactive maintenance, and ensuring seamless connectivity across dispersed petrol pump networks.

2.2 Integration of RFID and IoT for Real-time Monitoring and Management of Petrol Pump Operations

The paper delves into the integration of two cutting-edge technologies, Radio Frequency Identification (RFID) and the Internet of Things (IoT), to revolutionize the management of petrol pump operations[1]. By harnessing RFID tags to uniquely identify and track various elements such as fuel tanks, inventory, and equipment within the petrol pump premises, and leveraging IoT devices like sensors and cameras to collect real-time data, the system enables a comprehensive monitoring framework.

This integration facilitates remote, real-time monitoring and management of petrol pump operations, empowering owners and managers with unparalleled visibility and control regardless of their physical location. They can efficiently monitor fuel levels, track inventory movements, identify equipment malfunctions, and ensure adherence to safety and regulatory standards. This proactive approach enables swift intervention in case of anomalies, such as automatically triggering a reorder request when fuel levels are low or alerting maintenance personnel in the event of equipment breakdowns. Consequently, downtime is minimized, operational disruptions are mitigated, and customer service levels are enhanced.

Moreover, the amalgamation of RFID and IoT technologies strengthens security measures at petrol pumps. RFID tags serve as access control mechanisms, authenticating personnel, vehicles, and equipment accessing the premises, thereby reducing the risk of unauthorized access and fuel theft. Additionally, IoT sensors are instrumental in detecting abnormal activities or security breaches, promptly alerting relevant authorities or security personnel in real-time.

In essence, the integration of RFID and IoT technologies presents a holistic solution for optimizing the efficiency, security, and regulatory compliance of petrol pump operations. By capitalizing on the synergies between these technologies, petrol pump owners and operators can streamline operations, bolster security protocols, and ultimately enhance customer satisfaction.

2.3 Smart RFID-enabled Petrol Pump System for Sustainable Fuel Management

The paper ”Smart RFID-enabled Petrol Pump System for Sustainable Fuel Management” introduces an innovative approach to petrol pump management by integrating RFID technology into a smart system[2].

This system aims to promote sustainable fuel management practices while enhancing operational efficiency and customer service.

At its core, the system utilizes Radio Frequency Identification (RFID) technology to enable efficient tracking and management of fuel inventory and other assets within the petrol pump premises. RFID tags are strategically deployed to uniquely identify and monitor various components such as fuel tanks, dispensers, and equipment. This enables automated data collection and real-time monitoring of inventory levels, fuel consumption patterns, and equipment status.

The smart aspect of the system is further enhanced through the integration of advanced sensors and data analytics capabilities. These sensors collect data on factors such as fuel flow rates, environmental conditions, and customer traffic, providing valuable insights for optimizing operations and decision-making. By analyzing this data in real-time, petrol pump operators can identify trends, anticipate demand fluctuations, and implement proactive measures to optimize fuel usage and minimize waste.

One of the key objectives of the smart RFID-enabled petrol pump system is to promote sustainable fuel management practices. By leveraging RFID technology and real-time data analytics, the system facilitates efficient inventory management, reducing the likelihood of overstocking or shortages. Additionally, by optimizing fuel consumption and minimizing wastage, the system contributes to reducing environmental impact and promoting sustainability in fuel management practices.

Furthermore, the integration of RFID technology enhances operational efficiency and customer service at petrol pumps. Real-time monitoring of inventory levels enables timely replenishment of fuel stocks, ensuring availability for customers. Additionally, the system can streamline payment processes through RFID-based transactions, reducing wait times and improving overall customer experience.

2.4 Efficient Fuel Distribution and Inventory Management Using RFID Technology at Petrol Pumps

The paper titled ”Efficient Fuel Distribution and Inventory Management Using RFID Technology at Petrol Pumps” introduces a novel approach to optimizing fuel distribution and inventory management processes at petrol pumps through the integration of Radio Frequency Identification (RFID) technology[3]. The system aims to enhance operational efficiency, minimize errors, and improve overall management practices in the fuel distribution industry.

By leveraging RFID technology, the system enables seamless tracking and monitoring of fuel inventory throughout the supply chain, from storage tanks to dispensers at petrol pumps. RFID tags are strategically attached to fuel containers, storage tanks

Dispensing equipment, allowing for automated data capture and real-time visibility into inventory levels and distribution activities.

One of the key features of the system is its ability to streamline fuel distribution processes through RFID-enabled automation. By accurately tracking fuel inventory levels in real-time, the system can optimize delivery schedules and route planning, ensuring timely replenishment of fuel stocks at petrol pumps. This proactive approach minimizes the risk of stockouts and reduces the need for emergency deliveries, thereby enhancing operational efficiency and customer satisfaction.

Furthermore, the integration of RFID technology facilitates improved inventory management practices at petrol pumps. Real-time monitoring of inventory levels enables petrol pump operators to make informed decisions regarding stock replenishment, storage allocation, and order fulfillment. By leveraging RFID data, operators can identify trends, detect anomalies, and implement proactive measures to prevent stockouts or overstocking situations.

In addition to enhancing operational efficiency, the RFID-enabled system offers benefits in terms of error reduction and cost savings. By automating data capture and inventory management processes, the system minimizes the risk of human errors and discrepancies in fuel inventory records. This not only improves data accuracy but also reduces operational costs associated with manual inventory management and reconciliation efforts.

2.5 Optimization of Petrol Pump Operations Through RFID-based Automation and Machine Learning

The paper titled ”Optimization of Petrol Pump Operations Through RFID-based Automation and Machine Learning” presents a sophisticated approach to enhancing the efficiency and effectiveness of petrol pump operations by integrating Radio Frequency Identification (RFID) technology and machine learning algorithms[4]. This integration aims to optimize various aspects of petrol pump management, including inventory control, equipment maintenance, and customer service.

At the core of the proposed solution is the utilization of RFID technology for automated data capture and real-time monitoring of petrol pump operations. RFID tags are deployed to track fuel inventory, equipment status, and customer interactions within the petrol pump premises. By seamlessly collecting and transmitting data to a central management system, RFID technology enables petrol pump operators to have a comprehensive view of their operations and make informed decisions in real-time.

Furthermore, the integration of machine learning algorithms adds a layer of intelligence to the system, allowing for predictive analysis and optimization of petrol pump operations. By analyzing historical data collected through RFID technology, machine learning algorithms can identify patterns, trends, and anomalies in petrol pump operations.

This enables proactive maintenance scheduling, predictive inventory management, and personalized customer service strategies.One of the key benefits of the proposed system is its ability to optimize fuel inventory management through predictive analytics. By analyzing historical consumption patterns and external factors such as weather conditions and traffic volumes, machine learning algorithms can forecast future demand for fuel with high accuracy. This enables petrol pump operators to proactively adjust inventory levels, minimize stockouts, and reduce inventory holding costs.

Moreover, the integration of RFID-based automation and machine learning enables predictive maintenance of petrol pump equipment. By monitoring equipment performance metrics captured through RFID tags, machine learning algorithms can predict potential failures or malfunctions before they occur. This allows for timely maintenance interventions, minimizing downtime and ensuring uninterrupted operation of petrol pump facilities.

2.6 Enhancing Security and Efficiency in Petrol Pump Management Using Blockchain and RFID Technology

The paper titled ”Enhancing Security and Efficiency in Petrol Pump Management Using Blockchain and RFID Technology” presents an innovative approach to improving security and efficiency in petrol pump management by integrating Blockchain and Radio Frequency Identification (RFID) technologies[5].This integration aims to address critical challenges such as fuel theft, fraud, and operational inefficiencies prevalent in the petrol pump industry.

The proposed system leverages RFID technology to enable real-time tracking and monitoring of fuel inventory, equipment, and personnel within the petrol pump premises. RFID tags are deployed to uniquely identify and track assets, ensuring transparency and accountability in all operations. By seamlessly capturing and transmitting data to a centralized database, RFID technology provides petrol pump owners and managers with comprehensive visibility into their operations.

In addition to RFID technology, the system incorporates Blockchain technology to enhance security and integrity in petrol pump management. Blockchain, known for its decentralized and immutable ledger, ensures that all transactions and data recorded within the system are secure, transparent, and tamper-proof. This significantly reduces the risk of unauthorized access, fraud, and data manipulation, thereby enhancing trust and reliability in petrol pump operations.

One of the key benefits of the proposed system is its ability to prevent fuel theft and fraud through enhanced security measures. By integrating Blockchain technology, the system creates a secure and transparent audit trail of all fuel transactions, from procurement to sale. Any unauthorized or suspicious activities are immediately flagged and recorded on the Blockchain, enabling swift detection and mitigation of fraudulent activities.

Moreover, the integration of RFID and Blockchain technologies streamlines operational processes and improves efficiency in petrol pump management. Real-time monitoring of fuel inventory and equipment status allows for proactive maintenance scheduling and inventory management, reducing downtime and operational costs. Additionally, Blockchain technology enables seamless integration with supply chain partners and regulatory authorities, facilitating compliance with industry standards and regulations.

2.7 Application of RFID Technology in Petrol Pump Maintenance and Fault Detection

The paper titled "Application of RFID Technology in Petrol Pump Maintenance and Fault Detection" explores the utilization of Radio Frequency Identification (RFID) technology to enhance petrol pump maintenance practices and fault detection processes[6].This application of RFID technology aims to improve operational efficiency, reduce downtime, and enhance the reliability of petrol pump operations.

The paper begins by highlighting the critical importance of timely maintenance and fault detection in ensuring the smooth operation of petrol pumps. It then introduces RFID technology as a powerful tool for automating maintenance processes and enabling proactive fault detection.

RFID tags are strategically deployed on various equipment and components within the petrol pump premises, including fuel dispensers, storage tanks, and other critical infrastructure. These RFID tags enable the automatic identification and tracking of equipment, facilitating streamlined maintenance workflows and asset management practices.

One of the key advantages of RFID technology in petrol pump maintenance is its ability to enable predictive maintenance strategies. By continuously monitoring equipment status and performance metrics captured by RFID tags, petrol pump operators can identify potential issues and anomalies before they escalate into critical failures.

This proactive approach to maintenance minimizes downtime, reduces repair costs, and ensures uninterrupted operation of petrol pump facilities.

Furthermore, the paper discusses how RFID technology can facilitate fault detection and troubleshooting processes in petrol pumps. RFID-enabled sensors can detect abnormal conditions or malfunctions in equipment, triggering automatic alerts or notifications to maintenance personnel. This enables swift intervention and resolution of issues, minimizing disruptions to petrol pump operations and enhancing overall reliability.

2.8 Real-time Monitoring and Control of Petrol Pump Operations Through Cloud-based RFID System

The paper titled ”Real-time Monitoring and Control of Petrol Pump Operations Through Cloud-based RFID System” presents an innovative approach to petrol pump management by leveraging a cloud-based Radio Frequency Identification (RFID) system for real-time monitoring and control[7]. This system enables petrol pump operators to remotely monitor operations, streamline processes, and enhance overall efficiency through cloud-based technology.

The paper begins by emphasizing the importance of real-time monitoring and control in ensuring the smooth operation of petrol pumps. It then introduces the concept of a cloud-based RFID system, which combines RFID technology with cloud computing to enable seamless data collection, processing, and analysis.

RFID tags are deployed throughout the petrol pump premises to track various assets and activities, including fuel inventory, equipment status, and customer transactions. These RFID tags automatically transmit data to a cloud-based platform, where it is stored, processed, and made accessible to petrol pump operators in real-time.

One of the key advantages of the cloud-based RFID system is its ability to provide remote access to petrol pump operations. Through a web-based dashboard or mobile application, petrol pump operators can monitor fuel levels, track inventory movements, and oversee equipment status from anywhere with an internet connection. This remote monitoring capability enhances operational flexibility and enables proactive decision-making to address issues as they arise.

Furthermore, the paper discusses how the cloud-based RFID system facilitates data analysis and insights generation. By leveraging cloud computing resources, petrol pump operators can analyze RFID data to identify trends, predict demand patterns, and optimize operational workflows. This data-driven approach enables continuous improvement and optimization of petrol pump operations.

Additionally, the paper highlights the scalability and cost-effectiveness of the cloud-based RFID system. Cloud computing allows for the seamless expansion of the system to accommodate growing operational needs, while also minimizing upfront infrastructure costs.

2.9 RFID-enabled Petrol Pump Automation System for Improved Customer Service and Inventory Management

The paper titled ”RFID-enabled Petrol Pump Automation System for Improved Customer Service and Inventory Management” introduces an innovative system designed to enhance customer service and inventory management at petrol pumps through Radio Frequency Identification (RFID) technology[8]. This system is developed by the aim to streamline operational processes and improve overall efficiency in petrol pump operations.

At the heart of the system is RFID technology, which enables automatic identification and tracking of various assets and activities within the petrol pump premises. RFID tags are deployed on fuel tanks, dispensers, and other equipment to facilitate real-time monitoring and data capture. By automatically transmitting data to a centralized system, RFID technology provides petrol pump operators with up-to-date information on fuel inventory levels, equipment status, and customer transactions.

One of the key benefits of the RFID-enabled petrol pump automation system is its ability to improve customer service. With real-time visibility into fuel inventory levels, petrol pump operators can ensure that adequate supplies are available to meet customer demand at all times. Additionally, RFID technology can streamline payment processes by enabling contactless transactions, reducing wait times and enhancing the overall customer experience.

Furthermore, the system enhances inventory management practices at petrol pumps. By accurately tracking fuel consumption and inventory levels in real-time, petrol pump operators can optimize stock replenishment processes and minimize the risk of stockouts or overstocking. This proactive approach to inventory management helps to reduce operational costs and ensure efficient use of resources.

2.10 Cost-effective Implementation of RFID Technology for Petrol Pump Inventory Tracking and Management

The paper titled ”Cost-effective Implementation of RFID Technology for Petrol Pump Inventory Tracking and Management” explores strategies for implementing Radio Frequency Identification (RFID) technology in a cost-effective manner to track and manage inventory at petrol pumps[9]. This paper addresses the challenges associated with deploying RFID systems in the context of petrol pump operations while considering budgetary constraints.

The primary focus of the paper is to identify cost-effective approaches for deploying RFID technology without compromising on functionality or performance. The authors discuss various factors that contribute to the overall cost of RFID implementation, including hardware costs, software development, installation expenses, and ongoing maintenance and support.

To mitigate these costs, the paper proposes several strategies for optimizing RFID implementation at petrol pumps.

These include leveraging off-the-shelf RFID hardware and software solutions, adopting scalable and modular architectures, and prioritizing essential features and functionalities to minimize customization efforts.

Additionally, the paper emphasizes the importance of careful planning and resource allocation to ensure the success of RFID implementation projects.

By conducting thorough cost-benefit analyses and considering factors such as return on investment (ROI) and total cost of ownership (TCO). Petrol pump operators can make informed decisions about RFID deployment strategies.

Furthermore, the paper discusses the potential benefits of RFID technology in improving inventory tracking and management practices at petrol pumps. By accurately monitoring fuel inventory levels, RFID systems can help prevent stockouts, reduce shrinkage, and optimize supply chain operations. These benefits contribute to enhanced operational efficiency and cost savings over time.

2.11 Efficient RFID Implementation for Petrol Pump Automation

The paper titled ”Efficient RFID Implementation for Petrol Pump Automation” presents a comprehensive approach to implementing Radio Frequency Identification (RFID) technology for automating operations at petrol pumps[10].This paper focuses on achieving efficiency in RFID implementation to optimize processes and enhance operational performance in the petrol pump industry.

The primary objective of the paper is to outline strategies for deploying RFID technology efficiently, considering factors such as cost-effectiveness, scalability, and compatibility with existing infrastructure.The authors emphasize the importance of a well-planned implementation strategy to maximize the benefits of RFID automation while minimizing disruptions to petrol pump operations.

The paper discusses various aspects of RFID implementation, including hardware selection, software integration, and deployment strategies. It highlights the importance of choosing RFID hardware and tags that are suitable for the specific requirements of petrol pump operations, such as durability, read range, and data storage capacity.

Furthermore, the paper addresses challenges related to software integration and compatibility with existing petrol pump management systems. It proposes solutions for seamless integration of RFID data with backend systems, ensuring that real-time information is accessible to petrol pump operators for decision-making and analysis.

Additionally, the paper explores deployment strategies for RFID technology at petrol pumps, considering factors such as site layout, environmental conditions, and regulatory requirements. It offers guidance on optimal placement of RFID readers and tags to maximize coverage and accuracy in data capture.

The paper also discusses the potential benefits of RFID implementation for petrol pump automation, including improved inventory management, enhanced security, and streamlined operations. By leveraging RFID technology, petrol pump operators can optimize processes, reduce manual labor, and enhance overall efficiency in fuel dispensing and management.

2.12 Enhanced Efficiency and Security in Petrol Pump Operations Through RFID-based Automation

The paper titled ”Enhanced Efficiency and Security in Petrol Pump Operations Through RFID-based Automation” explores the application of Radio Frequency Identification (RFID) technology to enhance efficiency and security in petrol pump operations[11]. This paper investigates how RFID-based automation can streamline processes and improve overall performance in the petrol pump industry.

The primary focus of the paper is to demonstrate how RFID technology can be leveraged to automate various aspects of petrol pump operations, including inventory management, equipment maintenance, and customer service. By deploying RFID tags on fuel tanks, dispensers, and other assets, petrol pump operators can track inventory levels, monitor equipment status, and streamline transaction processes in real-time.

The paper highlights the role of RFID technology in improving efficiency by reducing manual intervention and streamlining workflows. RFID-enabled automation minimizes the need for manual data entry and reconciliation, leading to faster transaction times, reduced errors, and improved operational efficiency at petrol pumps.

Furthermore, the paper discusses how RFID technology enhances security in petrol pump operations by enabling better control and monitoring of access to critical assets and facilities. RFID tags can be used to authenticate personnel, vehicles, and equipment, reducing the risk of unauthorized access and fuel theft. Additionally, RFID-enabled surveillance systems can detect and deter security breaches in real-time, enhancing overall safety and security at petrol pump premises.

Additionally, the paper explores the potential benefits of RFID-based automation for improving customer service and satisfaction at petrol pumps. By automating transaction processes and ensuring accurate inventory management, RFID technology enables petrol pump operators to deliver faster service, minimize wait times, and enhance the overall customer experience.

2.13 Integration of RFID Technology for Improved Petrol Pump Management and Customer Service

The paper titled ”Integration of RFID Technology for Improved Petrol Pump Management and Customer Service” delves into the integration of Radio Frequency Identification (RFID) technology to enhance petrol pump management and customer service[12].This paper explores how RFID technology can optimize operational processes and elevate the quality of service provided to customers at petrol pumps.

The primary focus of the paper is to demonstrate the manifold benefits of integrating RFID technology into petrol pump operations. By deploying RFID tags on various assets and equipment, petrol pump operators can track inventory, monitor equipment status, and streamline transaction processes in real-time. This real-time visibility enables operators to make informed decisions, minimize errors, and optimize resource allocation, thereby enhancing overall operational efficiency.

Furthermore, the paper emphasizes the role of RFID technology in improving customer service at petrol pumps. By automating transaction processes and ensuring accurate inventory management, RFID technology enables petrol pump operators to deliver faster service, minimize wait times, and enhance the overall customer experience. Additionally, RFID-enabled loyalty programs and personalized service offerings can help build customer loyalty and drive repeat business.

Additionally, the paper discusses the potential challenges and considerations associated with integrating RFID technology into existing petrol pump management systems. It highlights the importance of interoperability, scalability, and data security in ensuring the successful implementation and adoption of RFID technology. By addressing these challenges proactively, petrol pump operators can maximize the benefits of RFID integration while minimizing disruptions to existing operations.

In summary, the ”Integration of RFID Technology for Improved Petrol Pump Management and Customer Service” paper underscores the transformative potential of RFID technology in the petrol pump industry. By leveraging RFID-based automation, petrol pump operators can achieve significant improvements in operational efficiency, customer service, and overall business performance, ultimately driving greater satisfaction and loyalty among customers.

2.14 Enhancing Petrol Pump Efficiency and Safety Through RFID-based Automation and Monitoring

The paper titled ”Enhancing Petrol Pump Efficiency and Safety Through RFID-based Automation and Monitoring” explores the utilization of Radio Frequency Identification (RFID) technology to improve efficiency and safety in petrol pump operations[13].

This paper investigates how RFID-based automation and monitoring systems can optimize processes and enhance safety protocols at petrol pumps.

The primary focus of the paper is to demonstrate the various ways in which RFID technology can be integrated into petrol pump operations to enhance efficiency and safety.

By deploying RFID tags on equipment, vehicles, and personnel, petrol pump operators can track assets, monitor activities, and enforce safety protocols in real-time. This real-time visibility enables operators to identify potential hazards, mitigate risks, and ensure compliance with safety regulations.

Furthermore, the paper highlights the role of RFID technology in improving operational efficiency at petrol pumps. By automating manual processes such as inventory management, Equipment maintenance, and transaction recording, RFID technology streamlines workflows, reduces errors, and minimizes downtime. This allows petrol pump operators to maximize productivity and optimize resource allocation, ultimately leading to improved operational efficiency.

Additionally, the paper discusses the potential benefits of RFID-based automation and monitoring systems for enhancing safety protocols at petrol pumps. RFID-enabled access control systems can restrict unauthorized access to sensitive areas and equipment, while RFID-enabled surveillance systems can detect and deter security breaches in real-time. By integrating RFID technology into safety protocols, petrol pump operators can create a safer working environment for employees and customers alike.

Moreover, the paper addresses the challenges and considerations associated with implementing RFID-based automation and monitoring systems in the petrol pump industry. It emphasizes the importance of interoperability, scalability, and data security in ensuring the successful deployment and adoption of RFID technology. By addressing these challenges proactively, petrol pump operators can maximize the benefits of RFID integration while minimizing disruptions to existing operations.

2.15 Utilization of RFID Technology for Petrol Pump Inventory Tracking and Control

The paper titled ”Utilization of RFID Technology for Petrol Pump Inventory Tracking and Control” examines the application of Radio Frequency Identification (RFID) technology to track and control inventory at petrol pumps[14]. This paper investigates how RFID technology can streamline inventory management processes and enhance control over stock levels at petrol pump facilities.

The primary focus of the paper is to demonstrate the benefits of utilizing RFID technology for inventory tracking and control in the petrol pump industry.

By deploying RFID tags on fuel tanks, storage containers, and other inventory items, petrol pump operators can accurately track the movement and consumption of fuel in real-time. This real-time visibility enables operators to maintain optimal stock levels, minimize stockouts, and reduce the risk of overstocking.

Furthermore, the paper discusses how RFID technology can improve inventory control practices at petrol pumps. By automating data capture and reconciliation processes, RFID technology reduces the need for manual intervention and streamlines inventory management workflows. This leads to improved accuracy, efficiency, and timeliness in inventory control activities, allowing petrol pump operators to make informed decisions and optimize resource allocation.

Additionally, the paper explores the potential challenges and considerations associated with implementing RFID technology for inventory tracking and control in the petrol pump industry. It addresses factors such as hardware selection, system integration, and data management, emphasizing the importance of careful planning and execution to ensure the successful deployment of RFID-based inventory control systems.

Moreover, the paper highlights the scalability and versatility of RFID technology for inventory management applications. RFID systems can be easily scaled to accommodate growing inventory volumes and evolving operational needs, making them suitable for petrol pump facilities of all sizes. Additionally, RFID technology can be integrated with existing inventory management systems to enhance functionality and extend the lifespan of legacy systems.

2.16 Integration of RFID and IoT for Real-time Monitoring and Management of Indian Petrol Pump Operations

The paper titled ”Integration of RFID and IoT for Real-time Monitoring and Management of Indian Petrol Pump Operations” explores the synergistic integration of Radio Frequency Identification (RFID) and Internet of Things (IoT) technologies to enhance the real-time monitoring and management of petrol pump operations specifically in the Indian context[15]. This paper addresses the unique challenges and opportunities presented by the Indian petrol pump industry and proposes a comprehensive solution leveraging RFID and IoT technologies.

The primary focus of the paper is to demonstrate how the integration of RFID and IoT technologies can revolutionize petrol pump operations by providing real-time visibility and control over critical assets and processes. By deploying RFID tags on equipment, fuel tanks, and other assets, petrol pump operators can track their location, status, and usage in real-time. Additionally, IoT sensors collect data from various sources, including RFID tags, fuel dispensers, and environmental sensors, enabling comprehensive monitoring and analysis of petrol pump operations.

Furthermore, the paper discusses the potential benefits of integrating RFID and IoT technologies for petrol pump operations in India. Real-time monitoring and management capabilities allow petrol pump owners and operators to optimize resource allocation, minimize downtime, and enhance operational efficiency.

Additionally, the data collected from RFID and IoT sensors can be analyzed to identify trends, predict maintenance needs, and optimize inventory management practices, leading to cost savings and improved customer service.

Additionally, the paper addresses the challenges associated with implementing RFID and IoT solutions in the Indian petrol pump industry, including infrastructure limitations, connectivity issues, and data security concerns. It proposes strategies for overcoming these challenges

Such as leveraging existing infrastructure, adopting scalable and modular solutions, and implementing robust security protocols to protect sensitive data.

Moreover, the paper highlights the potential impact of RFID and IoT integration on the Indian petrol pump industry, including improved operational efficiency, enhanced customer service, and increased competitiveness. By embracing RFID and IoT technologies, petrol pump operators in India can position themselves for future growth and success in an increasingly digital and connected world.

By harnessing the power of real-time data and advanced analytics, petrol pump operators can optimize their operations, improve customer satisfaction, and drive sustainable growth in the dynamic Indian market.

Integration of RFID and IoT for Real-time Monitoring and Management of Indian Petrol Pump Operations offers valuable insights into the transformative potential for the Indian petrol pump industry

2.17 Conclusion

In conclusion, the conducted literature survey has provided valuable insights into the integration of RFID and IoT for petrol pump operations management. The review highlights significant advancements in automated inventory tracking, operational efficiency, and customer service enhancements achieved through RFID-enabled automation and IoT-driven insights.

However, the survey also identifies persistent challenges such as privacy concerns, technical complexity, signal interference, and cost implications associated with RFID and IoT implementations in petrol pump environments. Despite these challenges, the literature survey reveals promising developments and innovative approaches that aim to address these issues effectively.

The project aims to build upon these advancements by focusing on scalability, remote monitoring capabilities, and the integration of novel solutions to enhance efficiency and usability in petrol pump operations. By leveraging the insights gained from the literature survey, the project is poised to contribute to the ongoing evolution of RFID and IoT applications in petrol pump management, aiming for improved operational efficiency and customer satisfaction.

Moreover, the literature survey underscores the importance of addressing key issues such as data security, interoperability of systems, and integration with existing infrastructure, which are crucial for the successful deployment of RFID and IoT solutions in petrol pump operations. Advances in sensor technology, cloud computing, and edge analytics further enhance the potential of RFID and IoT to revolutionize real-time monitoring and management in this sector.

Overall, the findings from this literature survey provide a comprehensive foundation for understanding current research trends, identifying critical challenges, and exploring potential avenues for innovation in the integration of RFID and IoT for real-time monitoring and management of petrol pump operations. This knowledge will guide future research and development efforts, enabling the project to address limitations and contribute meaningfully to advancing the field. By fostering collaboration between academia, industry stakeholders, and technology providers, the project seeks to accelerate the adoption of RFID and IoT solutions, paving the way for sustainable and efficient petrol pump operations in the digital age.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This outlines the detailed methodology adopted for the development and detailed implementation of the RFID-based petrol pump automation system. The primary aim of this system is to enhance the security, efficiency, and user experience of petrol dispensing operations through the integration of advanced microcontroller technology and various peripheral devices. At the core of this system is the ESP32 DevKit v1 microcontroller, which acts as the central processing unit, coordinating the functionalities of multiple components including the RFID module, keypad, flame sensor, ultrasonic sensor, buzzer, relay module, and LCD display.

The methodology section is divided into two main parts: the block diagram and the circuit diagram. The block diagram provides a high-level overview of the system architecture, illustrating the interconnections and interactions between various components. This diagram highlights how each part works together to achieve the desired functionality.

The circuit diagram, on the other hand, offers a detailed look at the specific electronic connections within the system. Together, these diagrams provide a comprehensive view of the system's design and integration, ensuring efficient and user-friendly operation. The combined insights from the block and circuit diagrams demonstrate the thoughtful planning and coordination involved in the system's development.

3.2 Block Diagram

The system comprises several interconnected components, each playing a crucial role in the efficient operation of the petrol pump. At the core of the system lies the ESP32 DevKit v1 microcontroller, serving as the central processing unit. It acts as the brain of the system, adapting the functionalities of various peripherals.

Authentication is facilitated by the RFID module (MFRC522), which reads RFID cards to grant access to authorized users. The keypad provides an alternative method for user input, allowing for password or PIN-based authentication. This dual authentication mechanism enhances security and prevents unauthorized access to the petrol pump.Safety measures are ensured through the integration of a flame sensor, which detects any fire incidents in the area of the petrol pump dispenser. In case of a fire hazard, appropriate actions can be triggered to mitigate risks and ensure the safety of users and the environment.

Petrol level monitoring is enabled by the ultrasonic sensor, which accurately measures the level of petrol in the storage tank.

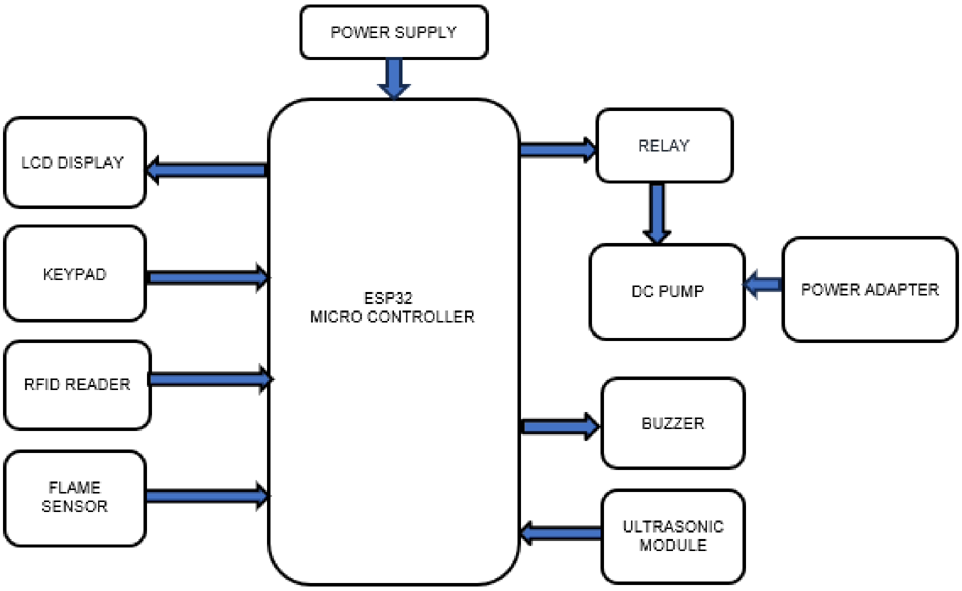

Figure 3.1: Block diagram of RFID Based Petrol Pump Automation System

This real-time monitoring prevents overflow or shortage of petrol, optimizing inventory management and ensuring a continuous supply of fuel to customers.

User feedback and alerts are provided through the buzzer, which emits audible signals to indicate authentication status, warn of potential hazards, or confirm successful operations. This enhances user interaction and ensures a seamless experience at the petrol pump.

Control of the petrol pump motor is managed by the relay module, which regulates the connection between the pump and the power source. The microcontroller controls the relay based on user authorization and safety conditions, ensuring smooth and controlled operation of the petrol pump.

A LCD provides a visual interface for users to view real-time system status, instructions, and feedback. This enhances user engagement and facilitates easy navigation of the petrol pump interface.

Overall, the block diagram depicts a comprehensive system architecture, integrating various components to create a secure, efficient, and user-friendly RFID-based Petrol Pump Automation System.

ESP32 DevKit board powered via micro USB connection from a 5V USB power adapter and DC Pump is powered by a 9v adapter.

3.3 Circuit Diagram

The smart petrol dispensing system embodies a sophisticated integration of various components, meticulously designed to ensure both efficiency and user-friendliness. At its core lies the ESP32 DevKit v1 microcontroller.

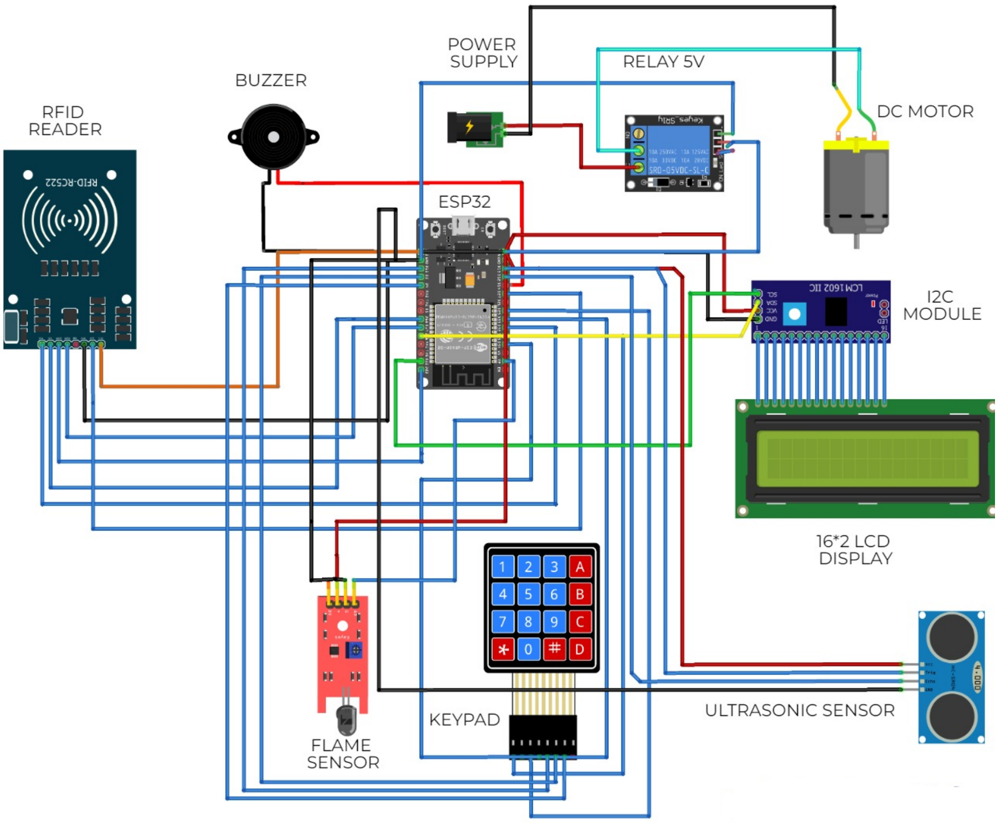

Figure 3.2: Circuit diagram of RFID Based Petrol Pump Automation System

A versatile and powerful unit that serves as the nerve center of the entire system. With its robust processing capabilities and ample connectivity options, the ESP32 DevKit v1 provides the computational backbone necessary to orchestrate the complex operations of the petrol dispensing system.

RFID Module (MFRC522) is Integrated with the microcontroller, the MFRC522 RFID module enables swift and secure authentication using RFID cards. It is connected via SPI, with specific pins allocated for data communication (SDA Pin D32, RST Pin D27).

A 4*3 Matrix keypad interface allows users to enter passwords and price for the purchase. It interfaces with the ESP32 microcontroller for data input and control.

16*2 LCD is Connected to the Microcontroller via the I2C interface (SDA Pin D21, SCL Pin D22 and Address 0x27), the LCD serves as the primary user interface, displaying real-time system status, instructions, and user prompts..

Flame Sensor is strategically placed near the petrol dispenser, the flame sensor detects potential fire hazards. It interfaces with the microcontroller via VP(GPIO 36) pin to trigger the buzzer.

Buzzer is wired to the microcontroller to the Pin D14, the buzzer provides audible feedback and alerts to users. It is used to indicate authentication status, system alerts, Petrol level alerts or Flame detections enhancing user engagement and interaction.

A 5v Relay Module is connected to Pin D5 of the microcontroller, the relay module regulates the petrol pump motor. It controls the flow of petrol based on user-entered prices, ensuring efficient dispensing operations.

The ESP32 DevKit v1 microcontroller board is powered via a micro USB connection from a 5V USB power adapter, ensuring stable operation and reliable performance. Additionally, the DC pump, operating at 9V, is powered by a compatible power adapter to facilitate the petrol dispensing process.

The positive terminal of the power adapter is connected to the COM (common) terminal of the relay, while one wire of the DC pump is connected to the NC (normally open) terminal of the relay to control the petrol dispensing process. The ground (GND) pin of the power adapter is joined with another wire of the DC pump to complete the circuit.

The ultrasonic sensor measures the level of petrol in the petrol storage tank. The Trig pin is connected to Pin D13, and the Echo pin is connected to Pin D12. This sensor ensures precise monitoring of petrol levels, enabling timely refills and preventing shortages.

3.4 Conclusion

In conclusion, the methodology outlined in this section provides an in-depth examination of the design and implementation processes for the RFID-based petrol pump automation system. The ESP32 DevKit v1 microcontroller serves as the central hub, orchestrating the operations of various interconnected components to deliver a seamless and secure user experience. The detailed block and circuit diagrams presented highlight the strategic integration of each component, ensuring a robust and efficient system architecture.

The system's dual authentication mechanism, combining the RFID module and keypad, significantly enhances security by preventing unauthorized access. The flame sensor adds a vital layer of safety by detecting potential fire hazards, while the ultrasonic sensor's real-time petrol level monitoring aids in effective inventory management. The inclusion of a buzzer and LCD display enhances user interaction by providing immediate auditory and visual feedback, facilitating a smooth and intuitive user experience. The relay module ensures controlled and safe fuel dispensing, governed by user input and safety conditions.

This meticulously designed system not only meets the current demands of secure and efficient petrol dispensing but also sets a foundation for future advancements in automated fuel management. By leveraging the capabilities of the ESP32 DevKit v1 microcontroller and a range of sensors and modules, the system achieves a high standard of performance, reliability, and user satisfaction. The methodology detailed in this chapter reflects a professional and thorough approach to system development, ensuring that the RFID-based petrol pump automation system is both innovative and practical in its application.

CHAPTER 4

SYSTEM DESIGN

4.1 Introduction

The system design phase of the RFID-based petrol pump automation project marks a critical stage where hardware and software converge to create a robust operational framework. This section focuses on detailing the integration and configuration of key hardware components, including the ESP32 DevKit v1 microcontroller, RFID module (MFRC522), keypad, sensors, and display. Each component is strategically chosen for its role in enhancing security, enabling precise petrol level monitoring, and providing intuitive user interaction at the petrol pump interface. Complementing these hardware selections is the Arduino IDE, pivotal in developing and integrating the necessary software functionalities tailored to the ESP32 microcontroller. Through meticulous configuration and interconnection, this chapter illustrates how these components synergistically contribute to achieving a reliable and user-friendly RFID-based petrol pump automation system.

This segment provides a concise overview of what the System Design will cover, emphasizing the integration of hardware and software components and their collective impact on the project's objectives.

4.2 Hardware Used

4.2.1 ESP32-WROOM 32 Microcontroller

The ESP32-WROOM-32 is a popular Wi-Fi and Bluetooth module based on the ESP32 system-on-a-chip (SoC) produced by Espressif Systems. It is widely used in various IoT (Internet of Things) applications due to its powerful features and low cost.
Here's a description of its major specifications:

1. **ESP32 SoC:** The heart of the module is the ESP32 chip, which integrates a dual-core Xtensa LX6 microprocessor, Wi-Fi and Bluetooth connectivity, and various peripherals. The microprocessor cores operate at a maximum frequency of 240 MHz.

2. **Wi-Fi:** The module supports 2.4 GHz Wi-Fi connectivity, complying with the IEEE 802.11b/g/n standard. It can function as a station (client) or as an access point (AP) for creating its own Wi-Fi network.

3. **Bluetooth:** The ESP32-WROOM-32 supports Bluetooth Classic and Bluetooth Low Energy (BLE). It allows wireless communication with other devices, such as smartphones, tablets, and other IoT devices.

Figure 4.1: ESP 32

4. **Flash Memory:** The module is equipped with a built-in SPI flash memory for program storage. The available flash memory size varies, but common options include 4MB, 8MB, or 16MB.

5. **RAM:** The ESP32-WROOM-32 provides on-chip RAM for data storage and program execution. The amount of available RAM is typically 520KB or more.

6. **GPIO Pins:** The module offers a range of general-purpose input/output (GPIO) pins that can be used to interface with external components and sensors. The exact number of GPIO pins depends on the specific variant of the module.

7. **Analog-to-Digital Converter (ADC):** The ESP32-WROOM-32 includes a 12-bit SAR ADC with multiple channels, allowing analog sensor readings.

8. **UART, I2C, SPI:** The module supports various communication interfaces, including Universal Asynchronous Receiver-Transmitter (UART), Inter-Integrated Circuit (I2C), and Serial Peripheral Interface (SPI). These interfaces enable communication with external devices and sensors.

9. **Power Management:** The module includes power management features such as voltage regulators and sleep modes, which help optimize power consumption for energy-efficient designs.

10. **Antenna:** The ESP32-WROOM-32 integrates an on-board antenna for Wi-Fi and Bluetooth communication. Some variants may offer an external antenna option for improved range.

Overall, the ESP32-WROOM-32 module provides a versatile platform for building IoT applications with Wi-Fi and Bluetooth connectivity, ample memory, and various interfaces for sensor integration and communication.

4.2.2 RFID Reader/Writer

The MFRC522 RFID reader and writer module represents a pinnacle of technological advancement in the domain of Radio Frequency Identification (RFID) systems. With its adept handling of 13.56 MHz frequency, this module demonstrates compatibility with a broad spectrum of RFID tags and cards, particularly those conforming to the ISO/IEC 14443 Type A standards. Beyond its frequency prowess, the MFRC522 module integrates seamlessly with microcontrollers, boasting a versatile communication interface primarily through SPI (Serial Peripheral Interface). This facilitates effortless integration with popular development platforms such as Arduino and Raspberry Pi, empowering developers to harness its capabilities for many applications.

Figure 4.2: RFID Reader

At its heart, the MFRC522 module encapsulates an amalgamation of sophisticated components, including an antenna, intricate control logic, and a robust communication interface. These elements synergize to deliver not only rapid and precise RFID tag detection but also bidirectional data exchange, enabling both reading and writing functionalities. This pivotal capability opens up a plethora of possibilities across various domains, ranging from access control and asset tracking to inventory management and beyond.

What sets the MFRC522 module apart is not only its technical process but also its unwavering reliability and efficiency.

Despite its diminutive form factor, this module boasts remarkable performance metrics, delivering swift read and write operations while consuming minimal power. This aspect renders it an ideal choice for applications where energy efficiency is paramount, including battery-powered devices and long-term deployments.

Furthermore, the MFRC522 module embodies a user-centric design philosophy, complemented by comprehensive documentation and a rich ecosystem of libraries and resources. This empowers developers of all skill levels to leverage its capabilities effectively, expediting the development cycle and fostering innovation across a spectrum of projects, from hobbyist endeavors to large-scale commercial deployments.

The MFRC522 RFID reader and writer module typically features a set of pins that facilitate its connection and interaction with external devices such as microcontrollers. Here's a brief description of its key pins:

1. **SDA (Serial Data):** This pin is used for serial data communication between the MFRC522 module and the microcontroller. It typically connects to the microcontroller's SPI data input/output pin.

2. **SCK (Serial Clock):** The SCK pin is responsible for synchronizing data transfer between the MFRC522 module and the microcontroller. It connects to the SPI clock pin of the microcontroller.

3. **MOSI (Master Out Slave In):** MOSI is the output from the microcontroller to the MFRC522 module during SPI communication. It carries data from the microcontroller to the module.

4. **MISO (Master In Slave Out):** MISO is the input to the microcontroller from the MFRC522 module during SPI communication. It carries data from the module to the microcontroller.

5. **IRQ (Interrupt Request):** The IRQ pin is used to signal the microcontroller when certain events occur, such as the detection of an RFID tag. It allows the microcontroller to respond promptly to these events.

6. **RST (Reset):** The RST pin is used to reset the MFRC522 module. It initializes the module to a known state and can be controlled by the microcontroller to initiate a reset sequence.

7. **3.3V and GND:** These pins provide power (3.3 volts) and ground connections for the MFRC522 module, ensuring proper operation and electrical stability.

8. **Antenna Connections:** Depending on the specific module design, there may be one or more pins dedicated to antenna connections. These pins facilitate the connection of external antennas for RFID communication.

4.2.3 RFID Tags

RFID tags are comprehensive systems consisting of several key components. Firstly, there's the antenna, which plays a crucial role in capturing energy from the RFID reader's radio frequency field. This energy is then utilized to power the tag and facilitate communication with the reader.

Figure 4.3: RFID Tags

Next there is the RFID chip or Integrated Circuit (IC), often referred to as the brain of the tag. This chip houses the necessary memory and processing circuitry for storing and handling data. It's responsible for modulating and demodulating the RF signal, managing data transmission and reception, and ensuring seamless communication with the reader.

Memory is another essential component of RFID tags, providing storage for data such as unique identifiers (UIDs) and application-specific information. Depending on the requirements, the memory capacity can vary widely, ranging from a few bits to several kilobytes or more. The substrate, on which the antenna and chip are mounted, serves as a foundation, offering physical support and protection for these components. It's designed to withstand environmental factors like moisture, temperature fluctuations, and mechanical stress.

Lastly, there's the encapsulation or housing, which shields the internal components from damage and external conditions. Materials such as plastic, epoxy, or silicone are commonly used for encapsulation, providing an additional layer of protection.

Additionally, encapsulation offers a surface for printing or attaching labels, allowing for further customization and information display, such as barcodes or logos.

Overall, each component plays a vital role in ensuring the functionality and durability of RFID tags across various applications

4.2.4 Flame Sensor

A flame sensor is an electronic device designed to detect the presence of a flame or fire. It typically works by sensing the infrared radiation emitted by a flame. When a flame is detected, the sensor sends a signal to a microcontroller or other control system, which can then trigger an alarm, shutdown a system, or activate a fire suppression system. Flame sensors are commonly used in fire detection and safety systems, as well as in industrial applications to monitor combustion processes.

Typically, a flame sensor employs a photodetector, often a photodiode or phototransistor, to detect the infrared (IR) or ultraviolet (UV) light emitted by the flame. Different types of flame sensors are available, including UV sensors that detect UV light emitted by a flame, and IR sensors that sense the infrared radiation from the flame. The choice of sensor type depends on the specific application and the type of flame to be detected.

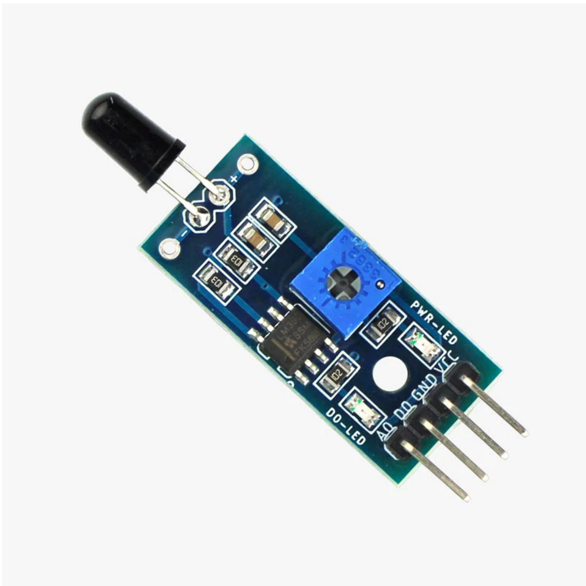

Figure 4.4: Flame Sensor

In operation, the flame sensor is positioned in close proximity to the burner or flame source, allowing it to continuously monitor the flame's presence. When the flame is detected, the sensor generates an electrical signal, which is sent to the control system. The control system then uses this signal to confirm that the flame is present and operating correctly. If the sensor fails to detect a flame or if the flame goes out unexpectedly,

The control system can initiate safety measures, such as shutting down the equipment or activating an alarm, to prevent potential hazards.

The reliability and accuracy of a flame sensor are crucial for the safe and efficient operation of heating systems, furnaces, boilers, and other combustion devices.Regular maintenance and calibration of the sensor are essential to ensure its proper functioning and to prevent false alarms or failures.

Additionally, flame sensors are often equipped with features such as self-checking capabilities and fault detection to enhance their reliability and safety.

In summary, a flame sensor is a critical safety component that plays a vital role in monitoring and controlling the combustion process in various heating systems and equipment. By detecting the presence or absence of a flame, the sensor helps to ensure the safe and efficient operation of the equipment, protecting against potential hazards and ensuring compliance with safety standards and regulations.

4.2.5 Relay Module

A relay is an electromechanical switch that uses an electromagnet to mechanically open or close electrical contacts. It consists of an electromagnet, a set of electrical contacts, and a spring mechanism. When an electrical current is applied to the electromagnet, it generates a magnetic field that attracts the spring-loaded contacts, causing them to close and complete the circuit. Conversely, when the current to the electromagnet is turned off, the contacts return to their original state due to the spring mechanism, opening the circuit.

Relays are commonly used in electrical and electronic circuits to control high-power devices with low-power signals.

They provide isolation between the control circuit and the load circuit, allowing for safe and efficient control of various devices such as motors, lights, heaters, and solenoids. Relays come in various configurations, including single-pole single-throw (SPST), single-pole double-throw (SPDT), double-pole double-throw (DPDT), and more, to suit different application requirements.

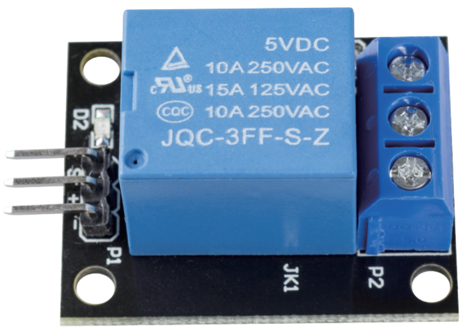

Figure 4.5: Relay Module

Relay modules often include screw terminals for easy and secure connection of the load circuit. They may also feature LED indicators to provide visual feedback on the status of the relay, such as when it is energized or not.

4.2.6 LCD

The 16x2 LCD module is a ubiquitous component in electronics projects, valued for its capability to display alphanumeric characters in a clear and easily readable format. Its design features a display panel divided into two lines, each accommodating up to 16 characters, providing users with a compact yet versatile visual output. This module typically interfaces with microcontrollers or other digital devices using communication protocols such as parallel or serial interfaces like SPI or I2C.

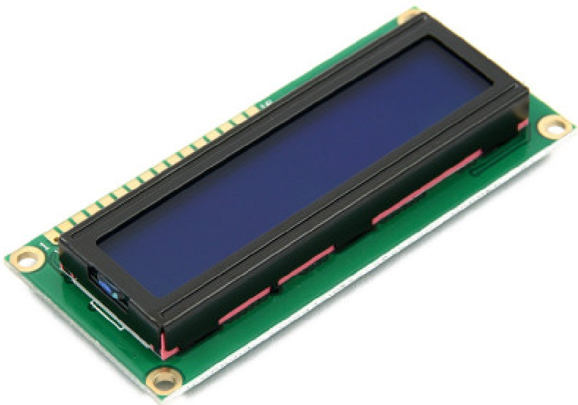

Figure 4.6: LCD display

Integral to the functionality of the 16x2 LCD module are the control signals RS (Register Select), RW (Read/Write), and E (Enable), which facilitate the management of data transfers between the microcontroller and the display. These signals dictate whether incoming data represents a command or character data, enabling precise control over the displayed content.In addition to its core functionality, many 16x2 LCD modules are equipped with supplementary features to enhance usability. For instance, an integrated backlight illuminates the display, ensuring readability in various lighting conditions. Furthermore, some modules offer a contrast adjustment mechanism, allowing users to fine-tune the display's contrast for optimal visibility.

Its ability to provide concise and immediate visual feedback makes it invaluable for displaying real-time data, status information, prompts, and user interfaces across diverse electronic devices and systems.

4.2.7 DC Pump

A DC pump is an electrical device that uses a direct current (DC) motor to move fluid, typically water or other liquids. DC pumps come in various types and configurations, including centrifugal pumps, diaphragm pumps, and submersible pumps, each designed for specific applications and fluid types.

Figure 4.7: DC Pump

DC pumps are commonly used in a wide range of applications, such as water circulation systems, aquariums, fountains, irrigation systems, and cooling systems. They offer the advantage of variable speed control and can be easily interfaced with electronic controllers for precise control of flow rate and pressure. DC pumps are available in different sizes and capacities to suit various requirements, from small, low-power pumps for hobbyist projects to large, high-capacity pumps for industrial applications.

4.2.8 Keypad

A keypad is a set of buttons arranged in a grid or matrix, typically used for entering numerical or alphanumeric input into electronic devices. Each button on the keypad corresponds to a specific electrical contact, which is activated when the button is pressed. Keypads are commonly used in various electronic devices, such as calculators, remote controls, security systems, and electronic door locks.

The 4x3 matrix keypad is a commonly used input device in electronics projects, providing a compact and intuitive interface for user interaction. It consists of a grid arrangement of buttons, with four rows and three columns, resulting in a total of 12 buttons.Interfacing the 4x3 matrix keypad with a microcontroller or other digital devices is typically achieved by connecting each row and column to input pins. This arrangement allows for multiplexing,

Figure 4.8: 4*3 Keypad

Where pressing a button closes a unique combination of row and column, enabling the microcontroller to identify which button has been pressed based on the activated row and column.

In operation, the microcontroller scans the rows and columns of the matrix keypad to detect button presses.

When a button is pressed, the corresponding row and column are identified, and the microcontroller registers the input accordingly. This process allows for efficient and reliable input detection, even with a relatively small number of input pins.

The 4x3 matrix keypad is versatile and suitable for various applications, including security systems, electronic locks, menu navigation interfaces, and more. Its compact size and straightforward interface make it a popular choice for projects where user input is required. Additionally, libraries and code examples are readily available for most microcontroller platforms, simplifying the integration of the keypad into projects and reducing development time.

4.2.9 Buzzer

A buzzer is an electronic sound-making device that produces a buzzing or beeping sound when activated.

It consists of a piezoelectric element that vibrates when an electrical signal is applied to it. Buzzer modules often include an integrated oscillator circuit, making them easy to interface with microcontrollers and other electronic circuits. Buzzer modules can be used for various purposes, such as indicating an alarm condition, providing feedback in user interfaces, or generating simple tones for audible alerts.

Figure 4.9: Buzzer

The design and construction of buzzers can vary depending on their intended application and the specific requirements of the device. Common types of buzzers include piezoelectric buzzers and magnetic buzzers.

Piezoelectric buzzers utilize the piezoelectric effect, where certain materials generate an electric charge when mechanical stress is applied. In a piezoelectric buzzer, an alternating current is applied to a piezoelectric element.

Causing it to expand and contract rapidly, which in turn generates sound waves. Piezoelectric buzzers are known for their high efficiency and durability, making them suitable for a wide range of applications.

4.2.10 Ultrasonic sensor

An ultrasonic sensor is a device that uses ultrasonic sound waves to measure distance or detect the presence of objects. It works by emitting a burst of ultrasonic sound waves and then listening for the echo reflected off an object. The sensor calculates the time taken for the sound waves to travel to the object and back, and uses this information to determine the distance to the object.

The ultrasonic sensor is a versatile and widely used component in electronics projects, valued for its ability to measure distances accurately and non-contact. It utilizes ultrasonic sound waves to determine the distance between the sensor and an object in its vicinity.

The operation of an ultrasonic sensor typically involves the emission of high-frequency sound pulses from a transducer element. These sound waves propagate through the air until they encounter an object in their path. Upon striking the object, the sound waves are reflected back towards the sensor.

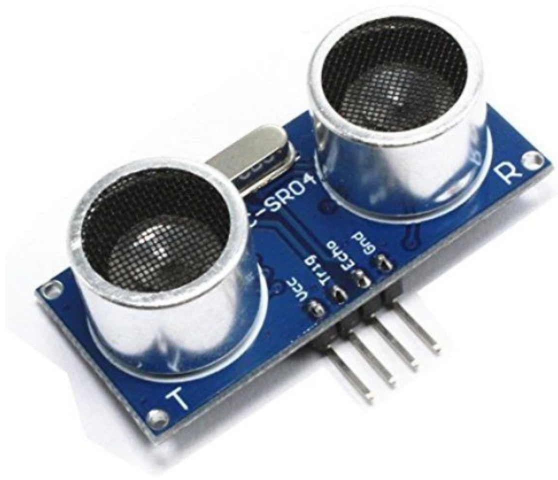

Figure 4.10: Ultrasonic sensor

By measuring the time it takes for the sound waves to travel to the object and return to the sensor, the ultrasonic sensor can calculate the distance to the object using the speed of sound in air as a reference. This distance measurement is often provided in units such as centimeters or inches, depending on the sensor's specifications.

Ultrasonic sensors are known for their accuracy and reliability, making them suitable for a wide range of applications.

Common uses include object detection, proximity sensing, obstacle avoidance in robotics, level sensing in industrial applications, and presence detection in security systems.

Overall, the ultrasonic sensor offers a reliable and effective solution for distance measurement and object detection in a wide range of electronic projects and applications, contributing to enhanced functionality and automation capabilities.

Ultrasonic sensors are commonly used in robotics, automation, and distance measurement applications. They are versatile and can be used in various environments, including indoors and outdoors, making them a popular choice for object detection and navigation in autonomous systems.

4.2.11 I2C Module

The I2C (Inter-Integrated Circuit) module serves as a pivotal communication protocol in embedded systems, seamlessly connecting microcontrollers with peripheral devices. At its core, the I2C protocol revolves around two essential signal lines: SDA and SCL. These lines facilitate bidirectional serial communication between multiple devices on the same bus.

Central to the I2C architecture is the master-slave relationship. In this setup, one device acts as the master, governing the communication flow, while other devices operate as slaves, responding to commands from the master. Each slave device is assigned a unique address, allowing the master to selectively initiate communication with specific slaves as needed.Data transmission in the I2C protocol occurs through clocked serial transfer. The master device generates clock pulses on the SCL line, orchestrating the timing of data exchange, while actual data flows bidirectionally on the SDA line.

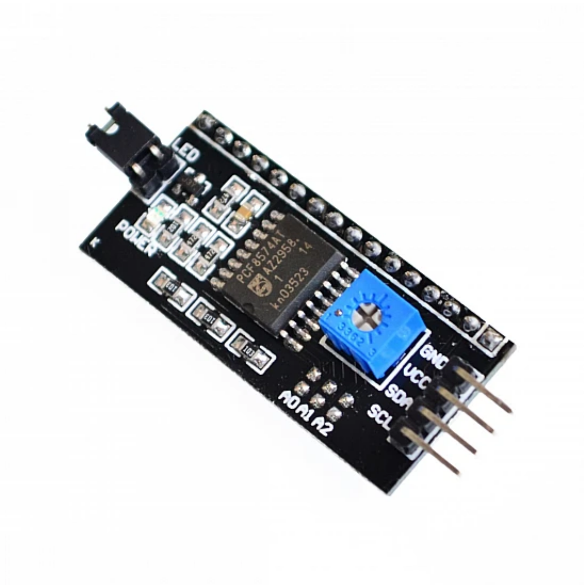

Figure 4.11: I2C Module

Communication sessions commence with a start condition, initiated by the master pulling the SDA line low while the SCL line remains high. This start condition signals the beginning of a communication transaction. Conversely, sessions conclude with a stop condition, indicated by the master releasing the SDA line while keeping the SCL line high, marking the end of communication.Acknowledgment plays a critical role in the I2C protocol, ensuring the integrity of data transmission. After receiving each byte of data, the recipient, whether master or slave, sends an acknowledgment signal, confirming successful reception.The speed of communication on the I2C bus is adaptable, accommodating various speeds based on the capabilities of the connected devices. Common speeds include Standard Mode (100 kHz), Fast Mode (400 kHz), and High-Speed Mode (3.4 MHz).

For signal stability, pull-up resistors are typically employed on both the SDA and SCL lines. These resistors ensure that the lines remain at a defined logic level when not actively driven by devices, contributing to reliable communication across the bus.In essence, the I2C module serves as a robust and efficient communication solution in embedded systems, facilitating seamless interaction between microcontrollers and peripheral devices in diverse applications.

4.2.12 5V Power Supply

In ESP32 DevKit, the power supply is facilitated by a USB micro cable, delivering a precisely regulated 5V output. This voltage is crucial as it aligns with the operating specifications of the ESP32 DevKit, which typically operates within a voltage range of 2.2V to 3.6V. While the ESP32 can technically function within this range, a stable 5V supply ensures optimal performance and longevity of the device's sensitive components.

The USB micro cable connects to various power sources, including computer USB ports, wall adapters, or power banks, offering versatility and convenience. Its widespread availability makes it an accessible option for powering electronic devices like the ESP32 DevKit.

Additionally, the need for a regulated 5V supply is underscored by the DevKit's power requirements. While the ESP32 DevKit can operate with lower voltages, a stable 5V supply is recommended to ensure consistent performance, especially during high-power tasks such as Wi-Fi or Bluetooth communication. By providing a reliable 5V supply, potential voltage fluctuations and instabilities are mitigated, safeguarding the ESP32 DevKit and ensuring uninterrupted operation for this project.

4.2.13 9V Wall Adapter

Figure 4.12: 9V Adapter

Integrating a 9V wall adapter into this project provides a reliable and convenient power source for the DC pump. With its plug-and-play design, it seamlessly connects to a standard outlet, offering stable DC power to ensure consistent pump operation.

It's compact size and lightweight construction make it easy to incorporate into this project setup without adding bulk or complexity.

Overall, the 9V wall adapter is an essential component that enhances the reliability and ease of use of this project, ensuring efficient pumping performance.

4.3 Software Used

4.3.1 Arduino IDE

The Arduino IDE (Integrated Development Environment) serves as a fundamental software tool tailored for programming Arduino microcontrollers. Its intuitive interface and comprehensive feature set streamline the process of coding, compiling, and uploading programs onto Arduino boards, catering to both novice and experienced developers alike.

At the core of the Arduino IDE is its code editor, providing a platform for crafting Arduino sketches (programs) with ease. Equipped with features such as syntax highlighting and auto-indentation, the editor enhances code readability and productivity, fostering a conducive environment for coding experimentation and refinement.

Complementing the code editor is the IDE's extensive code library, housing a wealth of pre-written functions and examples. This repository of resources empowers users to leverage existing code snippets for common tasks, accelerating development cycles and promoting code reusability across projects.

Underpinning the Arduino IDE's functionality is its robust compilation process. Equipped with a powerful compiler, the IDE translates Arduino code, typically written in C/C++, into machine language tailored for the target Arduino board.

This seamless translation ensures compatibility and optimal performance across a spectrum of Arduino hardware configurations.Moreover, the Arduino IDE features a bootloader component integral to the programming workflow. By facilitating the uploading of compiled code to Arduino boards via USB connection, the bootloader streamlines the deployment process, enabling swift iteration and testing of code changes on physical hardware.

In summary, the Arduino IDE stands as a cornerstone in the Arduino ecosystem, offering a user-centric environment for programming Arduino microcontrollers. With its user-friendly interface, comprehensive code editor, extensive code library, robust compilation capabilities, and seamless uploading functionality, the IDE empowers developers to unleash their creativity and bring their Arduino projects to life with unparalleled efficiency and ease.

4.4 Conclusion

The system design of the RFID-based petrol pump automation project meticulously integrates a variety of hardware components and sophisticated software tools to ensure a secure, efficient, and user-friendly solution. The hardware selection, including the ESP32 DevKit v1 microcontroller, RFID module (MFRC522), keypad, sensors, and display, plays a pivotal role in the overall functionality and performance of the system.

These components are carefully chosen for their specific capabilities in enhancing security, monitoring fuel levels, and facilitating seamless user interaction.

The ESP32 DevKit v1 microcontroller, serving as the system's central processing unit, provides the computational power and connectivity required for real-time operations and efficient communication between various peripherals. The RFID module ensures secure access control by authenticating users, while the keypad offers an alternative method for user input, adding an extra layer of security and flexibility. Sensors, such as the ultrasonic sensor for fuel level monitoring and the flame sensor for safety, contribute to the system's reliability and user safety. The LCD display enhances user experience by providing real-time feedback and operational status.

On the software front, the Arduino IDE is instrumental in developing and integrating the software functionalities tailored for the ESP32 microcontroller. Its user-friendly interface, comprehensive code editor, and extensive library support enable efficient coding, debugging, and deployment processes. The combination of these software tools with the robust hardware infrastructure ensures that the system can perform its intended functions effectively and reliably.

Overall, the integration of these hardware and software components results in a cohesive and robust RFID-based petrol pump automation system. This system not only enhances the operational efficiency of petrol dispensing but also ensures security, safety, and user satisfaction. The detailed system design laid out in this chapter underscores the strategic selection and configuration of components, setting a solid foundation for the implementation and testing phases that follow.

CHAPTER 5

PRODUCT DEVELOPMENT

5.1 Introduction

This section explores the development and implementation of the RFID-based Petrol Pump Automation System, focusing on the integration, interfacing, and testing of various technologies and components to create a seamless, efficient, and secure fuel dispensing solution. Key components such as the ESP32 microcontroller, RFID reader, keypad, DC pump, I2C LCD display, flame sensor, and buzzer were meticulously integrated through precise coding and circuit design, ensuring smooth communication and operation.

The implementation process began with prototyping on a breadboard, where individual components were tested for functionality and compatibility. Following successful breadboard testing, the components were transferred to a custom-designed Zero PCB, ensuring robust and reliable connections. Comprehensive testing was conducted at each stage to validate the system's performance and identify any necessary adjustments.

At the core of the system lies the ESP32 microcontroller, orchestrating functionalities seamlessly. The RFID reader enables secure user authentication, the keypad provides an intuitive interface, the DC pump ensures precise fuel dispensing, and the I2C LCD display offers real-time status updates. The flame sensor adds safety by detecting potential fires, and the buzzer provides audible alerts.

The system's connectivity can be enhanced with IoT and mobile integration, allowing remote monitoring and control via smartphones or tablets, thus optimizing efficiency and resource utilization.By meticulously integrating, interfacing, and testing these components, the RFID-based Petrol Pump Automation System offers enhanced security, efficiency, and user experience in petrol pump operations.

5.2 Implementation

5.2.1 Interfacing of RFID Reader

The integration of the MFRC522 RFID Reader Module with the ESP32 microcontroller in the Petrol Pump Automation System involves several key steps to ensure seamless communication and functionality.The MFRC522 module is physically connected to the ESP32 microcontroller using jumper wires or cables.

Each pin on the MFRC522 module (e.g., MOSI, MISO, SCK, SS, VCC, GND) must be connected to the corresponding pin on the ESP32 microcontroller according to the SPI communication protocol and power requirements specified in their datasheets.

The Serial Peripheral Interface (SPI) protocol is utilized for communication between the MFRC522 module and the ESP32 microcontroller. SPI enables high-speed and synchronous data exchange between devices. The ESP32 microcontroller acts as the SPI master, while the MFRC522 module serves as the SPI slave device.

To enable communication and interaction between the ESP32 microcontroller and the MFRC522 module, appropriate software libraries must be used. Arduino libraries designed specifically for the MFRC522 module provide essential functions and protocols for initializing the module, reading RFID tags, and performing other operations.

Upon system startup, the ESP32 microcontroller initializes the MFRC522 module by configuring its SPI interface and other necessary parameters. This initialization process prepares the MFRC522 module for operation and sets the stage for RFID tag detection and communication.

```
#include <SPI.h>
#include <MFRC522.h>
#define MFRC522_SDA_PIN 32
#define MFRC522_RST_PIN 27

MFRC522 mfrc522(MFRC522_SDA_PIN, MFRC522_RST_PIN);
void setup() {
    SPI.begin();
    mfrc522.PCD_Init();
    Serial.begin(9600); // Initialize serial communication
}
void loop() {
    if (mfrc522.PICC_IsNewCardPresent() && mfrc522.PICC_ReadCardSerial()) {
        String rfidData = "";
        for (byte i = 0; i < mfrc522.uid.size; i++) {
            rfidData += String(mfrc522.uid.uidByte[i] < 0x10 ? "0" : "");
            rfidData += String(mfrc522.uid.uidByte[i], HEX);
        }
        if (authenticateRFID(rfidData)) {
            // Authentication successful, proceed with further actions
        } else {
            // Authentication failed, proceed with other actions
        }
        delay(1000); // Delay for readability
    }
}
bool authenticateRFID(String rfidData) {
    String validRFID = "F31037DD"; // Valid UID
    return rfidData.equalsIgnoreCase(validRFID);
}
```

Figure 5.1: Interfacing of MFRC522 RFID Reader

Once initialized, the ESP32 microcontroller enters a continuous scanning loop, where it monitors the MFRC522 module for the presence of RFID tags or cards within its detection range. This scanning loop ensures that the system is always ready to detect and authenticate RFID tags in real-time.

When an RFID tag is detected by the MFRC522 module, the ESP32 microcontroller initiates SPI communication to retrieve the tag's unique identification (UID) code. The UID serves as a unique identifier for the tag and is essential for user authentication and identification purposes.The retrieved UID is compared against a pre-defined database of authorized tag UIDs stored within the system. If the UID matches an entry in the database, the ESP32 microcontroller proceeds with the authentication process, signaling successful authentication to the user through LCD display.

5.2.2 Interfacing of keypad

The 4x3 keypad matrix is physically connected to the ESP32 microcontroller using jumper wires or cables. The keypad typically has 7 output pins (rows) and 3 input pins (columns), making a total of 10 pins. Each row and column pin on the keypad must be connected to a corresponding GPIO pin on the ESP32 microcontroller.

The GPIO pins on the ESP32 microcontroller are configured to act as either input or output pins. The 7 output pins (rows) of the keypad are set as output pins, while the 3 input pins (columns) are set as input pins. This configuration allows the ESP32 to scan the keypad matrix and detect key presses.The ESP32 microcontroller employs a scanning algorithm to detect key presses on the keypad matrix. The algorithm typically involves sequentially activating each row (output) pin while monitoring the state of the column (input) pins.

By systematically scanning through each row and column combination, the microcontroller can determine which key (if any) is being pressed.

Once a key press is detected, the ESP32 microcontroller maps the corresponding row and column combination to a specific key value. This mapping allows the microcontroller to identify which key was pressed by the user. The key values are typically represented as alphanumeric characters or numeric codes.

```
#include <Keypad.h>

const byte ROWS = 4;
const byte COLS = 3;
char keys[ROWS][COLS] = {
  {'1','2','3'},
  {'4','5','6'},
  {'7','8','9'},
  {'*','0','#'}
};
byte rowPins[ROWS] = {35, 33, 25, 34};
byte colPins[COLS] = {15, 2, 4};
Keypad keypad = Keypad(makeKeymap(keys), rowPins, colPins, ROWS, COLS);

void loop() {
    char key = keypad.getKey();
    if (key != NO_KEY) {
        // Key pressed, proceed with next step
    }
}
```

Figure 5.2: Interfacing 4*3 Keypad

The detected key values can be used to trigger various actions or functions within the Petrol Pump Automation System. For example, pressing a specific key combination initiates a user to login with password and enter the price for petrol quantity.

5.2.3 Interfacing of LCD display

To interface the LCD display, the ESP32 needs to be equipped with an I2C module. The I2C module consists of two lines: SDA (Serial Data Line) and SCL (Serial Clock Line). These lines are used for bidirectional communication between the microcontroller and the LCD display.

The LCD display itself should support I2C communication and have an I2C interface module, often called an I2C backpack or I2C controller, integrated into it.

This module acts as a bridge between the LCD display and the ESP32, converting the I2C signals into commands and data that the display can understand.The connection between the ESP32 and the LCD display is straightforward. The SDA and SCL lines from the I2C module on the ESP32 are connected to the corresponding pins on the I2C backpack of the LCD display. Additionally, the I2C backpack may require power and ground connections, which should be connected to the appropriate pins on the ESP32.In terms of software, the ESP32 needs to be programmed to communicate with the LCD display via the I2C protocol. Libraries and functions specific to the ESP32 and the LCD display model can be used to simplify the programming process.

```
#include <Wire.h>
#include <LiquidCrystal_I2C.h>

#define SCREEN_WIDTH 16
#define SCREEN_HEIGHT 2
LiquidCrystal_I2C lcd(0x27, SCREEN_WIDTH, SCREEN_HEIGHT);

void setup() {
    lcd.init();
    lcd.backlight();
}

void loop() {
    lcd.setCursor(0, 0);
    lcd.print("Welcome,Scan your Petro-Card");
}

```

Figure 5.3: Interfacing of 16*2 I2C-LCD

Overall, interfacing an LCD display with an ESP32 using the I2C module offers a convenient and efficient way to display information. The I2C communication protocol simplifies the connection and data transfer process, while libraries and functions specific to the ESP32 and the LCD display model facilitate programming and control. This integration allows for the creation of interactive and visually appealing interfaces in a wide range of applications.

5.2.4 Interfacing of Flame Sensor

The flame sensor is physically connected to the ESP32 microcontroller using jumper wires or cables. The flame sensor typically has three pins: VCC, GND, and OUT. The VCC pin is connected to a 3.3V or 5V power source, the GND pin is connected to the ground (GND) of the ESP32, and the OUT pin is connected to a GPIO pin configured as an input. The GPIO pin on the ESP32 microcontroller connected to the OUT pin of the flame sensor is configured as an input pin. This configuration allows the ESP32 to monitor the digital output signal from the flame sensor, which indicates the presence or absence of a flame.

The ESP32 microcontroller continuously monitors the digital output signal from the flame sensor.

When a flame is detected, the flame sensor outputs a logic HIGH (1) signal, indicating the presence of a flame. The microcontroller reads this signal and takes appropriate action based on the application requirements.

```
#define FLAME_SENSOR_SIGNAL_PIN 39

void setup() {
    pinMode(FLAME_SENSOR_SIGNAL_PIN, INPUT);
}

void loop() {
    int flameValue = digitalRead(FLAME_SENSOR_SIGNAL_PIN);
    if (flameValue == HIGH) {
        // Flame detected, ring buzzer
    }
}

```

Figure 5.4: Interfacing of Flame Sensor

In a Petrol Pump Automation System, the flame sensor plays a critical role in ensuring safety by detecting potential fire incidents near the petrol dispenser. Upon detecting a flame, the ESP32 microcontroller can trigger safety protocols such as shutting down the petrol pump motor, activating alarms, or sending alerts to designated personnel.

5.2.5 Interfacing of Piezo electric Buzzer

Hardware The buzzer is physically connected to the ESP32 microcontroller using jumper wires or cables. The buzzer typically has two pins: positive (+) and negative (-). The positive pin is connected to a GPIO pin configured as an output, while the negative pin is connected to the ground (GND) of the ESP32.This configuration allows the ESP32 to control the buzzer by toggling the output voltage to produce sound.

```
#define BUZZER_PIN 14

void setup() {
    pinMode(BUZZER_PIN, OUTPUT);
}

void loop() {
    digitalWrite(BUZZER_PIN, HIGH);
    delay(500);
    digitalWrite(BUZZER_PIN, LOW);
    delay(500);
}

```

Figure 5.5: Interfacing of Piezo Electric Buzzer

To generate sound using the buzzer, the ESP32 microcontroller toggles the output voltage of the GPIO pin at a specific frequency. By varying the frequency of the toggling signal, the microcontroller can produce different tones or patterns of sound.

In a Petrol Pump Automation System, the buzzer can be used to generate alerts or notifications for various events or conditions.

For example, the buzzer may sound an alarm in case of emergencies such as fire detection, petrol overflow,invalid operations or system malfunctions buzzer can also provide feedback to users about the status or outcome of their actions.

5.2.6 Interfacing of Ultrasonic sensor

Connect the trigger pin of the ultrasonic sensor to a GPIO pin configured as an output on the ESP32. Connect the echo pin of the sensor to another GPIO pin configured as an input. Ensure the sensor's VCC and GND pins are connected to appropriate power and ground sources, respectively.

To initiate a distance measurement, the ESP32 sends a short pulse (typically 10 microseconds) to the trigger pin of the ultrasonic sensor.

This pulse triggers the sensor to send out an ultrasonic wave.The ultrasonic wave emitted by the sensor travels towards the object and reflects back. The echo pin of the sensor receives this reflected wave, generating a pulse.The ESP32 measures the time taken for the pulse to travel from the sensor to the object and back. This time, known as the "echo time," is directly proportional to the distance between the sensor and the object Where the speed of sound is approximately 0.034 cm/µs.

```
#define TRIGGER_PIN 13
#define ECHO_PIN 12

void setup() {
    pinMode(TRIGGER_PIN, OUTPUT);
    pinMode(ECHO_PIN, INPUT);
}

void loop() {
    digitalWrite(TRIGGER_PIN, LOW);
    delayMicroseconds(2);
    digitalWrite(TRIGGER_PIN, HIGH);
    delayMicroseconds(10);
    digitalWrite(TRIGGER_PIN, LOW);
    float duration = pulseIn(ECHO_PIN, HIGH);
    float distance = duration * 0.034 / 2;
    // Petrol Level Monitoring in Storage Tank
}
```

Figure 5.6: Interfacing of Ultrasonic Sensor

The ESP32 processes the echo time and calculates the distance using the formula. The calculated distance value is then utilized to determine the volume of petrol remaining in the tank. This real-time data on fuel levels is crucial for effective inventory management. It allows operators to monitor petrol levels continuously, ensuring that they are aware of when the fuel levels are low and need replenishment. This helps in planning timely refills, preventing stockouts, and maintaining uninterrupted service.

5.2.7 Interfacing of Relay

Connect the control pin of the relay module to a GPIO pin configured as an output on the ESP32. Ensure the relay module's VCC and GND pins are connected to appropriate power and ground sources, respectively. Additionally, connect the relay module's input terminals to the AC source and the load (e.g., petrol pump motor).

The ESP32 can control the relay module by toggling the state of the GPIO pin connected to its control pin. When the GPIO pin is set to HIGH, the relay is activated and allows current to flow from the AC source to the load. When the GPIO pin is set to LOW, the relay is deactivated, cutting off the current flow.

```
// Pin Declaration for Relay
#define RELAY_IN_PIN 5

void setup() {
    // Initialize Relay Pin as Output
    pinMode(RELAY_IN_PIN, OUTPUT);
}

void executePumpingSequence(float petrolPrice) {
    // Calculate time delays based on petrol price
    int onDelay  = int(petrolPrice * 10); // Example: On delay in milliseconds is 10 times the price
    int offDelay = int(petrolPrice * 20); // Example: Off delay in milliseconds is 20 times the price

    // Turn on the relay
    digitalWrite(RELAY_IN_PIN, HIGH);
    // Turn off the relay after a delay
    delay(onDelay);
    digitalWrite(RELAY_IN_PIN, LOW);
    // Wait for some time before turning on again
    delay(offDelay);
    // Turn on
```

Figure 5.7: Interfacing of Relay

Calculate the flow rate based on the petrol price entered by the user. This involves dividing the standard volume of petrol (1000 milliliters) by the petrol price per liter(108.47) to get 9.2191 ml for 1 rupee of petrol,and to get the flow rate for different amount the petrol price is multiplied with the standard flow rate.

The relay is controlled by a delay . The off delay, multiplied by 20, provides a longer interval between dispensing cycles for system cool down and reset, enhancing operational efficiency and safety.

5.3 Final Product

The RFID-based petrol pump automation system is designed to transform the conventional fuel dispensing process by integrating advanced RFID technology to automate user authentication, transaction processing, and fuel management. This comprehensive project follows a structured approach, beginning with breadboard-level assembly, advancing through PCB assembling, and culminating in thorough testing, including the critical aspect of petrol flow testing.

The initial stage, the breadboard-level assembly, serves to validate the design and functionality of the system's components. Key components such as the Arduino microcontroller,All the components are carefully placed on the breadboard.

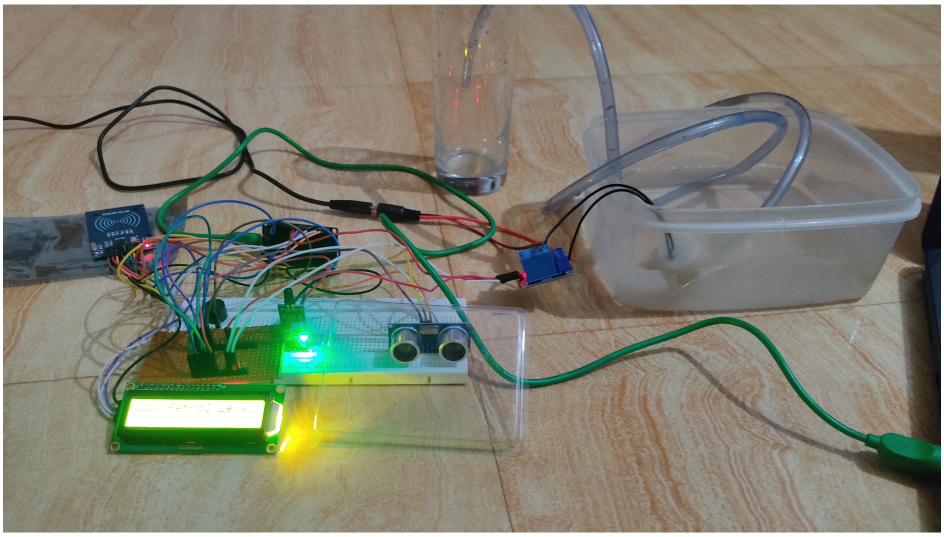

Figure 5.8: Bread Board Level Assembly

Figure 5.8 shows the bread board level assembly of the project.The RFID module is connected to the Arduino using SPI pins, the LCD display uses I2C pins, the keypad is attached via digital pins, and the relay module, flame sensor, ultrasonic sensor, and buzzer are connected to their respective pins. After completing the wiring, initial testing involves uploading the control code to the Arduino and individually validating the functionality of each component. This includes ensuring accurate RFID readings, functional keypad inputs, proper relay operation, and sensor responsiveness.

Following the successful prototype on the breadboard, the project progresses to the PCB assembly stage. The objective here is to create a more robust and compact version of the system. Next step is to design a layout in zero pcb and it is fabricated,after the fabrication they are inspected for defects, and components are soldered onto the board, ensuring reliable connections and no short circuits. The assembled PCB is then housed in an appropriate enclosure to protect the electronics while allowing user interaction and securing all external connections such as power and sensor interfaces.

The final stage involves rigorous testing and validation to ensure the system meets all design specifications and functions effectively in real-world scenarios. Functional testing is conducted by powering up the system and evaluating all features, including RFID scanning, transaction processing, and fuel management under various conditions. Performance testing assesses the system's response time, accuracy, and reliability, ensuring the relay controls the fuel pump accurately and the sensors detect conditions correctly.

A crucial part of the testing phase is the petrol flow testing, which verifies the system's ability to manage and monitor the dispensing of fuel accurately. This involves connecting the system to a controlled fuel pump and measuring the flow rate of petrol as it is dispensed. The RFID system authenticates users and triggers the relay to start fuel flow.

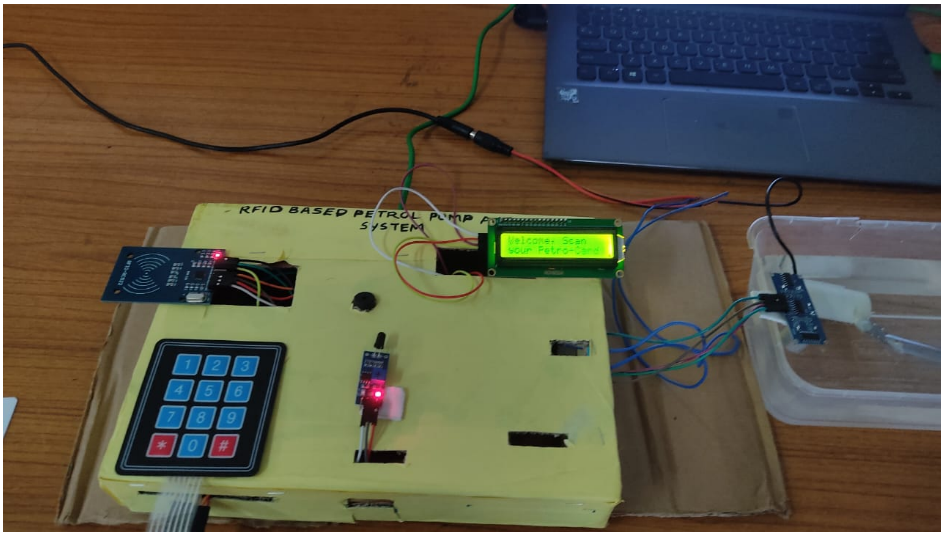

Figure 5.9: Final Product

The flow sensor monitors the volume of petrol dispensed, and this data is cross-checked with the transaction records for accuracy. By measuring the flow rate and ensuring it aligns with the user's input and payment, the system's precision and reliability in real-world fuel dispensing operations are confirmed. Additionally, safety protocols are tested to ensure that the system responds correctly to anomalies such as flame detection or irregular fuel levels, automatically shutting down the pump to prevent accidents.Figure 5.9 shows the Tested Final Product.

5.4 Conclusion

In conclusion, the successful development and implementation of the RFID-based Petrol Pump Automation System represent a significant milestone in modern fuel dispensing technology. Beginning with breadboard-level assembly, the project transitioned through meticulous PCB design and assembly, rigorous testing, and precise component interfacing to culminate in a fully functional and deployable solution.

The journey began with breadboard prototyping, where components were meticulously wired and configured to validate core functionalities. Through iterative testing and troubleshooting, the system's reliability and robustness were established, laying a solid foundation for subsequent stages. The design and soldering of the PCB further optimized the system's layout for compactness and efficiency while enhancing reliability and durability. Components were soldered onto the board with precision, ensuring electrical connectivity and signal integrity.

Testing played a crucial role throughout the development process, encompassing both individual components and the integrated system. Component-level testing validated functionality and performance, ensuring each part operated as expected.

System-level testing evaluated interoperability and reliability in real-world scenarios, confirming that all components worked together seamlessly.

Interfacing the final product involved integrating all components with precision, using the ESP32 microcontroller as the central hub for communication and control. Each component, including the RFID reader, keypad, DC pump, I2C LCD display, buzzer, and flame sensor, was meticulously tested and integrated to ensure smooth operation.For instance, the ESP32 processes data from the RFID reader to authenticate users, the keypad for user input, and the LCD display for real-time status updates. The DC pump is controlled for precise fuel dispensing, while the flame sensor enhances safety by detecting potential fire hazards. The buzzer serves as an alert mechanism for various system statuses and critical events.

Moreover, the ultrasonic sensor integration allows the ESP32 to calculate the distance for monitoring petrol levels in storage tanks. This real-time distance measurement prevents overflows, detects shortages, and manages inventory more effectively, ensuring the petrol pump operates smoothly without interruptions due to fuel shortages.

By thoroughly testing and integrating all these components, the system's overall functionality and reliability are significantly enhanced, ensuring efficient and secure fuel dispensing operations. This meticulous interfacing and comprehensive testing process guarantee that the RFID-based Petrol Pump Automation System meets the desired operational standards and performs efficiently.

Each component was interfaced with precision, following established protocols and standards to ensure compatibility and reliability. In essence, from breadboard-level assembly to PCB fabrication, testing, and final product interfacing, each stage of development exemplified meticulous attention to detail and a commitment to excellence. As the system continues to evolve and adapt, its impact on fuel management and operational efficiency is poised to be profound and far-reaching, shaping the future of the industry.

CHAPTER 6

CONCLUSION & FUTURE SCOPE

6.1 Conclusion

The incorporation of RFID (Radio Frequency Identification) technology into petrol pump automation heralds a transformative era in fuel dispensing systems, offering a myriad of benefits across various operational facets..One of the paramount advantages of RFID-based petrol pump automation lies in its ability to streamline operations. By seamlessly integrating RFID tags into vehicles and RFID readers into fuel dispensers, the process of fueling becomes remarkably efficient. Customers no longer need to manually input data or handle payment cards, significantly reducing transaction times and queues during peak hours. This efficiency not only enhances customer satisfaction but also optimizes resource utilization for petrol pump operators.

With a focus on sustainability, efficiency, and technological innovation, this project sets the stage for a future where refueling processes are seamless, secure, and tailored to the evolving needs of consumers and vehicles.The RFID-based Petrol Pump Automation System represents a significant advancement in the fuel dispensing industry, offering streamlined operations, enhanced security, and improved user experience. By leveraging RFID technology along with innovative features such as autonomous vehicle integration and advanced authentication methods,the Petrol Pump Automation System offers a glimpse into the future of smart and seamless refueling experiences also the system promises to revolutionize the way petrol refueling is conducted.This adaptability ensures that petrol pump facilities remain at the forefront of innovation, continuously evolving to meet the evolving needs and expectations of stakeholders.

In conclusion, the implementation of RFID-based petrol pump automation represents a pivotal milestone in modernizing and securing fuel dispensing processes. By fostering efficiency, security, and data-driven insights, this project not only enhances the operational capabilities of petrol pump facilities but also lays the foundation for future technological innovations in the realm of energy distribution and management.

6.2 Future Scope

The future scope of this project envisions a highly advanced and versatile petrol pump automation system that seamlessly integrates with emerging technologies like Internet of Things (IoT), Blockchain, 5G connectivity, Edge Computing, GSM and embedded systems a to the evolving needs of modern vehicles and consumers. This next-generation system aims to revolutionize the refueling experience by incorporating the following key features:

Autonomous Vehicle Integration: The system is designed to seamlessly integrate with autonomous vehicle platforms, enabling autonomous vehicles to autonomously navigate to the petrol pump, refuel, and make payments without human intervention. Vehicle-to-infrastructure communication protocols will facilitate smooth interaction between the petrol pump system and autonomous vehicles, ensuring efficient and hassle-free refueling experiences.

Vehicle-to-Vehicle Communication: Leveraging vehicle-to-vehicle communication technology, the system will enable vehicles to share real-time fuel level data with each other and with the petrol pump system. This allows for predictive refueling recommendations and optimized route planning, ensuring vehicles refuel at the most convenient times and locations.

Versatility for Different Fuel Types and Vehicles: The system is designed to accommodate various fuel types, including petrol, diesel, electric, and hydrogen, catering to the diverse needs of different vehicle types and emerging technologies. This versatility ensures that the system remains relevant and adaptable to future advancements in automotive propulsion systems.

Integration with Emerging Technologies: The system will continuously evolve to integrate with emerging technologies such as blockchain, augmented reality (AR), and artificial intelligence (AI). Blockchain-based transaction processing will ensure secure and transparent fuel transactions, while AR-based mobile applications will provide users with real-time assistance and guidance during the refueling process. AI-powered analytics will enable predictive maintenance and dynamic pricing strategies, enhancing operational efficiency and customer satisfaction.

Mobile Integration and Fast Tag Technology: Mobile integration will allow users to interact with the petrol pump system remotely via dedicated mobile apps or mobile dialers, enabling seamless authentication, fuel selection, and payment processing from their smartphones. Additionally, fast tag technology will be implemented to enable automatic RFID-based authentication, similar to toll plaza systems, further streamlining the refueling process for users.

Sustainability and Environmental Impact: The system will prioritize sustainability and environmental impact by promoting the use of alternative fuels and renewable energy sources. Integration with electric vehicle charging stations and hydrogen fueling stations will encourage the adoption of cleaner and more sustainable transportation options, contributing to environmental conservation efforts..

Global Interoperability Standards: Develop and promote global interoperability standards for RFID-based petrol pump automation systems, enabling seamless integration and interoperability between systems deployed in different countries and regions. This facilitates cross-border travel and ensures a consistent user experience for international drivers.

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APPENDIX A
PROGRAM

```
#include <Arduino.h>
#include <SPI.h>
#include <MFRC522.h>
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
#include <Keypad.h> // Include Keypad library

// Pin Declarations
#define MFRC522_SDA_PIN         32
#define MFRC522_RST_PIN         27
#define FLAME_SENSOR_SIGNAL_PIN 36
#define RELAY_IN_PIN            5
#define BUZZER_PIN              14
#define TRIGGER_PIN             13
#define ECHO_PIN                12
// Keypad Pins
const byte ROWS = 4; //four rows
const byte COLS = 3; //three columns
char keys[ROWS][COLS] = {
  {'1','2','3'},
  {'4','5','6'},
  {'7','8','9'},
  {'*','0','#'}
};
byte rowPins[ROWS] = {35, 33, 25, 34}; //connect to the row pinouts
byte colPins[COLS] = {15, 2, 4};//connect to the column pinouts
Keypad keypad = Keypad(makeKeymap(keys), rowPins, colPins, ROWS, COLS);

// LCD Dimensions
#define SCREEN_WIDTH  16
#define SCREEN_HEIGHT 2

// Global Variables
char password[] = "1234";
```

```
int  balanceAmount = 50000;

LiquidCrystal_I2C lcd(0x27, SCREEN_WIDTH, SCREEN_HEIGHT);
MFRC522 mfrc522(MFRC522_SDA_PIN, MFRC522_RST_PIN);

void setup() {
    pinMode(RELAY_IN_PIN, OUTPUT);
    digitalWrite(RELAY_IN_PIN, HIGH); // Turn relay on initially
    pinMode(FLAME_SENSOR_SIGNAL_PIN, INPUT);
    pinMode(BUZZER_PIN, OUTPUT);
    pinMode(TRIGGER_PIN, OUTPUT);
    pinMode(ECHO_PIN, INPUT);

    lcd.init();
    lcd.backlight();
    SPI.begin();
    mfrc522.PCD_Init();

    checkFlameSensor();// Check flame sensor
    checkPetrolLevel();// Check petrol level

    Serial.begin(9600);
    while (!Serial); // Wait for Serial to initialize

    lcd.clear();
    lcd.print("Welcome, scan");
    lcd.setCursor(0, 1);
    lcd.print("your Petro-card");
}

void loop() {
    char key = keypad.getKey(); // Check for keypad input
    if (key != NO_KEY) { // If key is pressed
        if (key == '#') { // '#' to confirm entry
        } else if (key == '*') { // '*' to clear input
            lcd.clear();
        } else {
            lcd.print('*');
```

```
        }
    }

if (mfrc522.PICC_IsNewCardPresent() && mfrc522.PICC_ReadCardSerial()){
        lcd.clear();
        lcd.setCursor(0, 0);
        lcd.print("Authenticating...");
        delay(2000);

        String rfidData = "";
        for (byte i = 0; i < mfrc522.uid.size; i++) {
        rfidData += String(mfrc522.uid.uidByte[i] < 0x10 ? "0" : "");
        rfidData += String(mfrc522.uid.uidByte[i], HEX);
        }
        if (authenticateRFID(rfidData)) {
            lcd.clear();
            lcd.print("Access Granted");
            delay(2000);
            lcd.clear();
            lcd.print("Enter Password:");
            Serial.println("Enter Password:");

            String enteredPassword = readSerialUntilHash();
            if (enteredPassword == password) {
                lcd.clear();
                lcd.print("Password Correct");
                delay(2000);
                Serial.println("Enter Price :");
                lcd.clear();
                lcd.print("Enter the Price:");

                String price = readSerialUntilHash();
                float petrolPrice = price.toFloat();
                if (petrolPrice > balanceAmount) {
                    lcd.clear();
                    lcd.print("Not sufficient balance");
                } else {
                    executePumpingSequence(petrolPrice);
```

```
                }
                clearSerialBuffer();
            } else {
                lcd.clear();
                lcd.print("Wrong Password");
                buzz(); // Buzz 3 times for wrong password
            }
        } else {
            lcd.clear();
            lcd.print("Invalid Card");
            buzz(); // Buzz 3 times for invalid card
        }
        delay(2000);
        lcd.clear();
        lcd.print("Welcome, scan");
        lcd.setCursor(0, 1);
        lcd.print("your Petro-card");
    }

    // Check flame sensor during entire program
    checkFlameSensor();
    // Check petrol level
    checkPetrolLevel();
}

String readSerialUntilHash() {
    String input = "";
    while (!Serial.available()); // Wait for input
    while (Serial.available()) {
        char c = Serial.read();
        if (c == ' ') break; // '#' to confirm input
        if (c == '.') { // '*' to clear input
            lcd.clear();
            continue;
        }
        if (c >= 32 && c <= 126) { // Printable characters
            input += c;
            lcd.print('*'); //
```

```
        }
        delay(10); // Debounce delay
    }
    return input;
}

bool authenticateRFID(String rfidData) {
    // Valid card UID: F31037DD
    return (rfidData.equalsIgnoreCase("F31037DD"));
}

void executePumpingSequence(float petrolPrice) {
    float petrolAmount = petrolPrice * 9.218;
    lcd.clear();
    lcd.print("Flow Rate:");
    lcd.setCursor(0, 1);
    lcd.print(petrolAmount);
    lcd.print(" ml");
    delay(2000);
    lcd.clear();
    lcd.print("Processing...");
    delay(2000);
    updateBalance(petrolPrice);

    // Display updated balance
    lcd.clear();
    lcd.print("Balance: ");
    lcd.print(balanceAmount);
    delay(2000);

    controlRelay(petrolPrice);//
}

void controlRelay(float price) {
    // Calculate time delays based on petrol price
    int onDelay  = int(price * 10);
    int offDelay = int(price * 20);
```

```
    // Turn on the relay
    digitalWrite(RELAY_IN_PIN, HIGH);
    // Turn off the relay
    delay(500);
    digitalWrite(RELAY_IN_PIN, LOW);
    delay(offDelay);
    digitalWrite(RELAY_IN_PIN, HIGH);
    lcd.clear();
    lcd.print("Thank you for");
    lcd.setCursor(0, 1);
    lcd.print("Filling Fuel");
}

void buzz() {
    digitalWrite(BUZZER_PIN, HIGH);
    delay(500);
    digitalWrite(BUZZER_PIN, LOW);
    delay(500);
}

void checkPetrolLevel() {
    // Simulated logic for checking petrol level
    float petrolLevel = measurePetrolLevel();
    // Measure petrol level using ultrasonic sensor
    if (petrolLevel > 12) {
        lcd.clear();
        lcd.print("Low Petrol Level");
        buzz(); // Buzz 3 times for low petrol level
    }
    else {
        // If petrol level is not low, display the welcome message
        lcd.clear();
        lcd.print("Welcome, scan");
        lcd.setCursor(0, 1);
        lcd.print("your Petro-card");
    }
}
```

```
float measurePetrolLevel() {
    // Triggering ultrasonic sensor to measure distance
    digitalWrite(TRIGGER_PIN, LOW);
    delayMicroseconds(2);
    digitalWrite(TRIGGER_PIN, HIGH);
    delayMicroseconds(10);
    digitalWrite(TRIGGER_PIN, LOW);
    // Measuring the duration of the pulse from ECHO_PIN
    float duration = pulseIn(ECHO_PIN, HIGH);
    // Calculating distance based on duration
    float distance = duration * 0.034 / 2;
    //Speed of sound is 0.034 cm/µs
    return distance;
}

void checkFlameSensor() {
    int flameValue = analogRead(FLAME_SENSOR_SIGNAL_PIN);

    if (flameValue < 4095) {
        digitalWrite(BUZZER_PIN, HIGH);
        lcd.clear();
        lcd.print("Fire detected!");
    } else {
        digitalWrite(BUZZER_PIN, LOW);
    }
}

void updateBalance(float petrolPrice) {
    balanceAmount -= petrolPrice;
}

void clearSerialBuffer() {
    while (Serial.available()) {
    Serial.read(); // Clearing each character in the buffer
    }
}
```