RAILWAY GATE CONTROL MONITORING SYSTEM

ELECTRONIC DESIGN PROJECT II

A PROJECT REPORT

Submitted by

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BONAFIDE CERTIFICATE

Certified that this project report titled **“RAILWAY GATE CONTROL MONITORING SYSTEM”** is the bonafide work of **EZHILAN K (811721106034), HARIHARAN P (811721106041), HARISH SHIVENDRA B (811721106047), LOGESHWARAN R (811721106061)** who carried out the project under my supervision. Certified further, that to the best of my knowledge the work reported herein does not from part of any other project report or dissertation on the basis of which a degree or award was conferred on an earlier occasion on this or any other candidate.

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We jointly declare that the project report on **"RAILWAY GATE CONTROL MONITORING SYSTEM"** is the result of original work done by us and best of our knowledge, similar work has not been submitted to **"ANNA UNIVERSITY CHENNAI"** for the requirement of Degree of **BACHELOR OF ENGINEERING**. This project report is submitted on the partial fulfilment of the requirement of the award of Degree of **BACHELOR OF ENGINEERING**.

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ABSTRACT

The present design and implementation of an automated railway gate control system utilizing an Arduino microcontroller. The primary objective of this system is to enhance safety and efficiency at railway crossings, mitigating the risk of accidents and facilitating smooth traffic flow. The system employs two infrared (IR) sensors positioned on either side of the railway crossing to detect the presence of an approaching train. Upon detection, signals are transmitted to the Arduino controller, which then activates a servo motor to lower the railway gates. Concurrently, an LCD display updates to show the status of the gate providing clear, real-time information to nearby pedestrians and drivers.

Additional safety and alert mechanisms include LED lights and a buzzer. The LED lights serve as visual indicators of the railway gate's status, flashing when the gate is in operation to alert approaching traffic. The buzzer sounds when the gate begins to close, providing an audible warning to further enhance safety measures at the crossing. The system's design also incorporates a feedback loop where the second IR sensor confirms the train has completely passed before initiating the gate opening sequence. This double-check mechanism ensures the gates remain closed as long as the train is in the crossing area, thereby preventing premature opening.

Through Arduino-based control, the system benefits from being cost-effective, programmable, and adaptable to various railway environments. Preliminary tests demonstrate that the system operates reliably under different scenarios, potentially reducing human error and increasing the safety at railway crossings. The successful deployment of this automated system could serve as a model for future implementations in railway safety technology.

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LIST OF ABBREVIATIONS

EEPROM	-	Electrically Erasable Programmable Read-Only Memory
EMB	-	Electromechanical Brake
EMU	-	Electric Multiple Unit
GND	-	Ground
IDE	-	Integrated Development Environment
I/O	-	Input/Output
IR	-	Infrared sensor
IDII	-	Interaction Design Institute Ivrea
LC	-	Level Crossings
LCD	-	Liquid Crystal display
LED	-	Light Emitting Diode
LSTM	-	Long Short-Term Memory
PWM	-	Pulse Width Modulation
SPI	-	Serial Peripheral Interface
SRAM	-	Static Random Access Memory
TWI	-	Two-Wire Interface
UART	-	Universal Asynchronous Receiver Transmitter
USB	-	Universal Serial Bus
VIN	-	Input Voltage

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

The railway gate controller is an essential component in the infrastructure of rail transport, designed to ensure the safe and efficient management of railway crossings. As railways intersect with roads at various points, these crossings pose significant safety risks if not managed properly. The primary function of a railway gate controller is to automate the operation of gates at these crossings, preventing collisions between road vehicles and trains, which can have catastrophic consequences.

Historically, the operation of railway gates was managed manually, relying on human operators to open and close barriers based on the train schedules or visual sighting of an approaching train. However, with the advent of technology and the increase in both train and vehicular traffic, manual operation has proven to be less efficient and potentially more hazardous. Thus, the development and implementation of automated railway gate controllers have become pivotal (Figure 1.1 explains the present Railway gate controller).

An automated railway gate controller integrates various technologies, including sensors, signal processing, and communication systems, to detect the presence of an approaching train. Upon detection, the system automatically initiates the closure of gates well before the train reaches the crossing, ensuring that vehicles and pedestrians are cleared from the tracks. Additionally, the system monitors the speed and position of the train continuously to calculate the optimal time to open the gates after the train has passed, minimizing wait time for road users while maximizing safety.

This introduction to the railway gate controller highlights its role and importance in modern rail systems, aiming to underscore the vital balance between operational efficiency and public safety. Through technological advancements, the railway gate controller continues to evolve, incorporating more sophisticated algorithms and connectivity features to further enhance its reliability and responsiveness in real-world applications.

1.2 EMBEDDED SYSTEM

An embedded system is one kind of a computer system mainly designed to perform several tasks like to access, process, store and also control the data in various electronics-based systems. Embedded systems are a combination of hardware and software where software is usually known as firmware that is embedded into the hardware. One of its most important characteristics of these systems is, it gives the o/p within the time limits. Embedded systems support to make the work more perfect and convenient. So, we frequently use embedded systems in simple and complex devices too. The applications of embedded systems mainly involve in our real life for several devices like microwave, calculators, TV remote control, home security and neighbourhood traffic control systems, etc.

Figure 1.1 Railway Gate Controller

An embedded system is integration of hardware and software, the software used in the embedded system is set of instructions which are termed as a program. The microprocessors or microcontrollers used in the hardware circuits of embedded systems are programmed to perform specific tasks by following the set of instructions. These programs are primarily written using any programming software like Proteus or Lab-view using any programming languages such as C or C++ or embedded C. Then, the program is dumped into the microprocessors or microcontrollers that are used in the embedded system circuits.

1.3 NEED FOR OUR PROPOSED WORK

The railway gate controller is a crucial system that manages the interaction between road traffic and trains at railway crossings. Its main purpose is to enhance safety by automating the opening and closing of gates to prevent accidents between vehicles or pedestrians and trains. The system uses sensors and cameras to detect approaching trains, calculate their speed and distance to the crossing, and initiate gate closures before the train arrives. After the train passes, the controller determines the appropriate time to reopen the gates, minimizing disruption to traffic while maintaining safety. The effectiveness of the controller relies on its integration with real-time monitoring systems and communication networks, which help coordinate actions across the railway line and adapt to changes in train schedules or speeds.

CHAPTER 2

LITERATURE SURVEY

Ajay Kapu et.al (2024) the automation of railway gate systems using IoT (Internet of Things) technology has gained significant attention due to its potential to enhance safety, efficiency, and convenience in railway operations. This literature survey aims to provide an overview of existing research and developments in this field, focusing on key concepts, methodologies, challenges, and future directions. The automation of railway gate systems using IoT holds great promise for improving safety, efficiency, and reliability in railway operations. By leveraging IoT technologies and innovative approaches, researchers and practitioners can address existing challenges and unlock new opportunities for enhancing railway gate automation. The work of Ajay Kapu, Shivashankar, and Raghava, as highlighted in their journal paper, contributes to the growing body of knowledge in this important field. Railway gate systems play a crucial role in ensuring the safety of railway crossings by controlling the movement of vehicles and pedestrians across railway tracks. Traditional railway gate systems are often manually operated, leading to inefficiencies, delays, and safety concerns. IoT-based automation solutions offer real-time monitoring, control, and management of railway gate operations, improving safety and efficiency.

Djordjevic et.al (2024) the rail level crossings (LCs) are critical points where railway tracks intersect with roads, presenting potential risks if not managed efficiently. To address this, Boban Djordjevic and collaborators propose an optimization-based digital twin to automate LC operations. This virtual replica employs optimization techniques to monitor and control LCs effectively, with the primary goal of ensuring safety for both trains and road users. By simulating various scenarios and utilizing real-time data, the digital twin predicts risks and adjusts LC operations dynamically, minimizing accident likelihoods and enhancing overall safety. It tackles challenges such as equipment failures and errors through continuous monitoring and prompt corrective actions, reducing accident probabilities stemming from malfunctions. Additionally, it optimizes waiting times for road users without compromising safety, adapting LC operations based on traffic flow and train schedules. This optimization contributes to smoother traffic flow and enhances the overall user experience at rail level crossings. In essence, this optimization-based digital twin represents a significant advancement in modern transportation systems, enhancing safety, minimizing equipment failures, and optimizing traffic flow through advanced techniques and real-time data analysis.

Malse et.al (2024) the automation of railway gate control systems is a critical aspect of railway safety and efficiency. The integration of automated control mechanisms ensures timely and accurate operation of railway gates, thereby minimizing the risk of accidents at railway crossings. This literature survey aims to provide an overview of existing research and developments in the field of automatic railway gate controllers, focusing on key concepts, methodologies, implementations, and future directions. Automatic railway gate controllers play a vital role in ensuring the safety and efficiency of railway crossings. By leveraging sensor technologies, control algorithms, and decision-making strategies, researchers and practitioners can develop effective solutions for automating railway gate operations. The journal paper authored by Malse, Noopur, Swami Malode, and Prit Mali contributes valuable insights to this field and serves as a foundation for further research and development in automatic railway gate control systems. Automatic railway gate controllers are designed to automate the opening and closing of railway gates based on the detection of approaching trains. These systems utilize a combination of sensors, actuators, and control algorithms to ensure the safe and efficient operation of railway gates. The primary objective of automatic railway gate controllers is to prevent collisions between trains and vehicles/pedestrians at railway crossings

Padovano et.al (2024) a simulation-based digital twin approach to enhance safety management within railway stations. They emphasize the growing importance of prioritizing safety and efficient pedestrian traffic management in railway environments. Central to their approach is the utilization of Digital Twins (DTs), which are virtual replicas mirroring real-world systems with unprecedented fidelity. By employing simulation-based models embedded within the DT framework, station managers gain a powerful tool to plan and assess various scenarios without affecting the actual operational environment. This enables exploration of diverse operational configurations, evaluation of safety protocols, and refinement of pedestrian traffic management strategies with precision and flexibility. However, the effectiveness of this approach relies heavily on the accuracy and validity of the underlying simulation models. Ensuring faithful representation of actual railway station operations is crucial for deriving meaningful insights and recommendations. Any discrepancies or inaccuracies within the simulation model could compromise the reliability of findings, underscoring the importance of meticulous model calibration and validation processes. Ultimately, Padovano research highlights the transformative potential of simulation-based digital twins in railway safety management, offering station managers a versatile platform for scenario exploration, risk assessment, and optimization of safety outcomes and pedestrian traffic management strategies within railway environments.

Selvakumar et.al (2024) railway crossing accidents are a significant safety concern worldwide, often resulting in severe casualties and property damage. Traditional railway gate control systems rely heavily on manual operations, which are prone to human error and inefficiency. The integration of Artificial Intelligence (AI) and Internet of Things (IoT) offers a promising solution to automate and enhance the reliability of railway gate control systems. The paper by Selvakumar, Mani Maran, and Janani presents an innovative approach to this issue through the design and development of an AI-assisted railway gate controlling system using IoT. The research by Selvakumar, Mani Maran, and Janani presents a significant advancement in the field of railway safety and automation. By integrating AI and IoT, they offer a novel solution to enhance the reliability and efficiency of railway gate control systems. Their work lays a strong foundation for future developments in intelligent transportation systems, with the potential to significantly reduce railway crossing accidents and improve operational efficiency. Prior research has explored various methods to improve railway crossing safety, including mechanical automation and sensor-based systems. However, these solutions often lack the integration of advanced AI algorithms and IoT capabilities, which can provide real-time data processing and decision-making. The motivation behind this study is to leverage the advancements in AI and IoT to create a more robust, efficient, and intelligent railway gate control system.

Sujatha et.al (2024) introduce a system for Automatic Gate Control on Railways, aiming to tackle the critical issue of level crossing accidents. This system is designed to automate railway level crossing gate control units, with the primary goal of significantly reducing accidents at these junctures by eliminating human error and ensuring timely gate closure when trains approach. By focusing on these high-risk areas where railways and roads intersect, the system seeks to mitigate the inherent dangers associated with level crossings, thereby enhancing overall safety in transportation environments. Automating gate control operations not only improves efficiency by facilitating swift gate closure and reopening in response to train movements but also reduces reliance on manual operation, minimizing delays and errors. This proactive approach not only enhances safety but also enhances traffic flow and minimizes disruption for both railway and road users. In essence, Mrs. R. Sujatha and her team's project offers a proactive solution to mitigate level crossing accidents, ultimately contributing to accident-free level crossing areas and safer travel experiences for all stakeholders.

Sun et.al (2024) introduce a novel method for indirectly measuring dynamic stress on metro bogies using Long Short-term Memory (LSTM) neural networks in the frequency domain. Their approach involves analyzing vibration signals from the bogie frame to estimate stress levels, offering the advantage of potentially reducing the number of sensors and wires needed for stress measurement, thereby lowering installation and maintenance costs. However, a significant challenge lies in the requirement for a substantial amount of data to train and validate the LSTM network, which may not always be readily available or feasible to collect in real-world scenarios. Despite these challenges, the method presents significant benefits by providing a data-driven approach to indirectly estimate dynamic stress, leading to improved monitoring and maintenance of metro bogies. The reduction in sensor and wiring requirements simplifies system deployment and maintenance, making it a promising avenue for enhancing metro bogie monitoring practices.

Vinit Kumar K et.al (2024) introduce an Automated Railway Level Crossing Gate Control System designed to bolster safety at railway level crossings. The system utilizes motion sensors for train detection and motor controllers to automate gate operations. Additionally, buzzers are incorporated to alert individuals of gate closure, adding an extra layer of safety. However, the system faces potential challenges related to component decay over time, which could jeopardize its reliability and effectiveness. To mitigate this risk, proactive maintenance and inspection protocols are crucial to promptly address any deterioration. Furthermore, stringent quality control measures during manufacturing and installation can enhance the system's longevity and reliability. By proactively managing component decay, stakeholders can uphold the safety and functionality of the Automated Railway Level Crossing Gate Control System, ensuring continued safety for pedestrians and vehicles at railway crossings.

Wang et.al (2024) have delved into fault diagnosis methods for Electric Multiple Unit (EMU) braking control systems, as detailed in their 2024 paper in "Machines." Their focus is on integrating deep learning techniques to enhance fault diagnosis in the electromechanical brake (EMB) system of EMUs. This system is vital for ensuring safe EMU operation by swiftly identifying and addressing faults. By incorporating deep learning algorithms, their method aims to improve fault detection and diagnosis accuracy and efficiency. However, implementing such advanced technology entails significant initial costs, covering technology acquisition, training, and system integration. This includes acquiring hardware and software, providing specialized training for personnel, and possibly upgrading existing EMU systems. Despite these challenges, the potential benefits are substantial. By leveraging deep learning, the system can detect and diagnose faults more quickly and accurately, reducing downtime and enhancing EMU reliability. This ultimately improves safety for passengers and operators while optimizing maintenance efforts and costs long-term. In summary, Wang et al.'s research offers a promising approach to enhancing fault diagnosis in EMU braking control systems through deep learning integration, with potential long-term benefits outweighing initial investment challenges.

Zulwidad et.al (2024) the operational efficiency and safety of railway systems are critical for effective transportation management. Manual operation of multiple railway guard posts can be labor-intensive and prone to human error, leading to delays and safety concerns. The paper by Zulwidad, Hisam, and Sulistiyowati addresses these issues by proposing an automated single system to manage multiple railway guard posts, aiming to enhance efficiency and safety through automation. The research by Zulwidad, Hisam, and Sulistiyowati presents a significant advancement in railway automation by proposing a centralized system for managing multiple railway guard posts. Their work demonstrates how automation can enhance operational efficiency, improve safety, and reduce labor costs. This study provides a strong foundation for future developments in railway automation and highlights the potential of integrating advanced technologies to create smarter and safer railway systems. Traditional railway guard posts require human operators to manage gate controls, monitor train movements, and ensure safety. This manual approach is not only resource-intensive but also susceptible to errors and inefficiencies. The motivation behind this study is to explore how automation can streamline these operations, reduce the reliance on manual labor, and improve overall safety and efficiency in railway management.

CHAPTER 3

EXISTING AND PROPOSED SYSTEM

3.1 EXISTING METHOD

1. **Manual Operation by Gatekeeper**: This traditional method involves a gatekeeper manually controlling the opening and closing of railway gates based on visual or auditory cues of approaching trains. While reliant on human intervention, it can be reliable when executed effectively, particularly in low-traffic areas where gatekeepers have clear visibility and adequate training. However, human error or distraction can pose risks, highlighting the importance of proper training and supervision.
2. **Timed Operation:** In this approach, railway gates operate on a predetermined schedule, opening and closing at specific intervals regardless of train activity. While less common due to safety concerns if a train approaches when the gates are open, it may be suitable for areas with predictable train schedules and minimal road traffic. However, the lack of flexibility and real-time adaptation to changing conditions can be a limitation.
3. **Remote Operation:** Remote operation allows for centralized control of railway gates from a control center or monitoring station. Operators can monitor train schedules, traffic conditions, and gate status in real-time, enabling efficient gate operations while ensuring safety (Figure 3.1explains the Existing method of Railway gate controller). This method offers flexibility and responsiveness, particularly in high-traffic areas or during emergencies, but relies on reliable communication and power supply.
4. **Interlocked Operation with Signal Systems:** Interlocking railway gate operations with signal systems synchronizes gate movements with train signals. When a train signal indicates an approaching train, the gates close automatically, ensuring safety by preventing vehicles from crossing the tracks. Once the train has passed, the gates reopen, minimizing disruptions to road traffic. This method

enhances safety and efficiency by eliminating the reliance on human intervention and ensuring timely gate movements in coordination with train movements.

5. **Emergency Override:** Emergency provisions, such as manual override mechanisms, are essential for situations like malfunctions or power outages. These mechanisms enable immediate opening or closing of railway gates by authorized personnel, ensuring the safety of road users and trains. While rarely used, emergency overrides provide a critical safety feature and must be regularly maintained and tested to ensure reliability.
6. **Communication Systems:** Effective communication systems facilitate coordination between railway staff, road users, and control centers, ensuring synchronized gate operations with train movements and traffic conditions. This includes communication between gatekeepers, train operators, traffic controllers, and emergency responders, enabling timely responses to incidents and minimizing the risk of accidents. Reliable communication infrastructure is essential for maintaining safety and efficiency in railway gate operations.

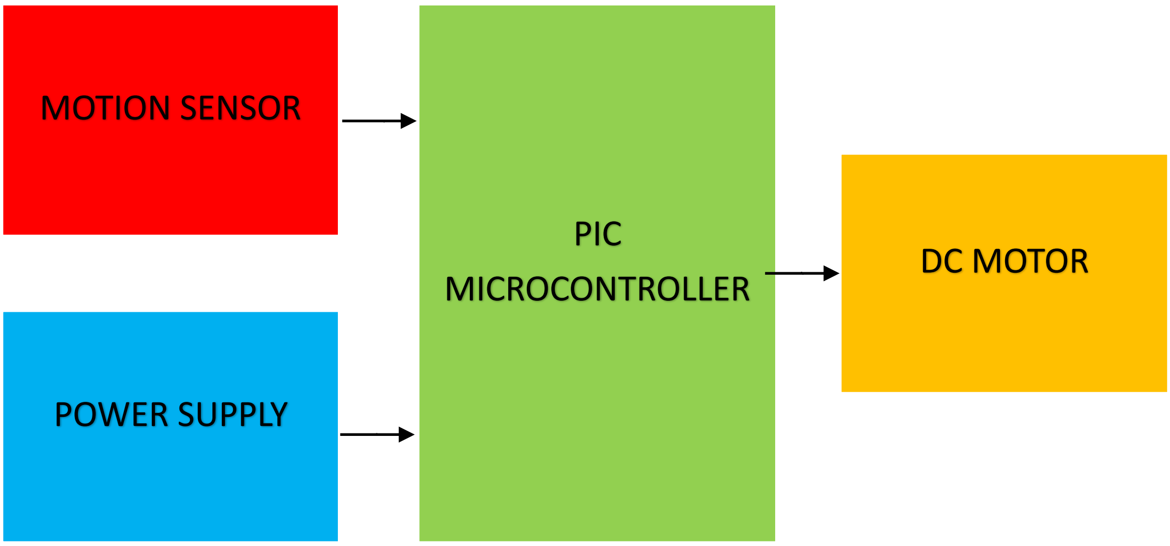

Figure 3.1 Existing Method

3.1.1 Disadvantages

1. **Manual Operation by Gatekeeper:** Relies on human intervention, which can be prone to errors or delays, especially during high-stress situations. Requires

constant monitoring and attention from gatekeepers, which may not always be feasible.

2. **Timed Operation:** Less flexible and adaptable to unpredictable situations, such as unexpected train delays or changes in traffic patterns. May pose safety risks if trains arrive when gates are open, potentially leading to accidents.
3. **Remote Operation:** Vulnerable to technical failures or communication disruptions, which could affect the timely operation of railway gates. Requires reliable infrastructure and continuous monitoring to ensure effective remote control.
4. **Interlocked Operation with Signal Systems:** Complexity of interlocking systems may increase maintenance requirements and costs. Requires careful coordination between gate operations and signal systems to avoid conflicts or errors.
5. **Emergency Override:** Manual override mechanisms may not always function correctly in emergency situations, leading to delays in gate operations. Dependence on manual intervention during emergencies can increase the risk of accidents.
6. **Communication Systems:** Reliance on communication systems introduces potential points of failure, such as network outages or equipment malfunctions. Inadequate communication between stakeholders could result in miscoordination and safety hazards at railway crossings.

3.2 PROPOSED METHOD

The Automatic Railway Gate Controller system, which integrates IR sensors and an Arduino microcontroller, revolutionizes railway operations with several notable advantages over traditional manual methods. The system employs infrared sensors to detect approaching trains, providing accurate and reliable responses irrespective of environmental conditions, ensuring consistent performance in varied weather. The Arduino microcontroller acts as the central processing unit, efficiently receiving signals from the sensors and promptly initiating the movement of the gates. This automation streamlines operations and significantly reduces the dependency on manual intervention, thereby minimizing the potential for human error or delays that can occur with manual gate operation.

Moreover, the system features a high-speed alerting mechanism to warn train drivers and road users about approaching level crossings. These alerts can be delivered through digital displays or wirelessly transmitted to nearby vehicles, enhancing situational awareness and safety for all parties involved. Visual indicators, such as LEDs, provide clear and unmistakable signals regarding the status of the gates, while audible alerts in the form of buzzer sounds ensure that road users and pedestrians are adequately informed of the gate status, further enhancing safety at crossings.

Additionally, the integration of an LCD display into the Railway Gate Controller significantly improves communication and provides real-time updates. This display can convey vital information, including train schedules, gate status, and safety messages, ensuring that both train operators and road users are well-informed at all times. The combined effect of these features is a substantial enhancement in safety, reliability, and efficiency of railway operations. It ensures a safer and more efficient rail transport environment (Figure 3.2 Describes the Proposed method block diagram).

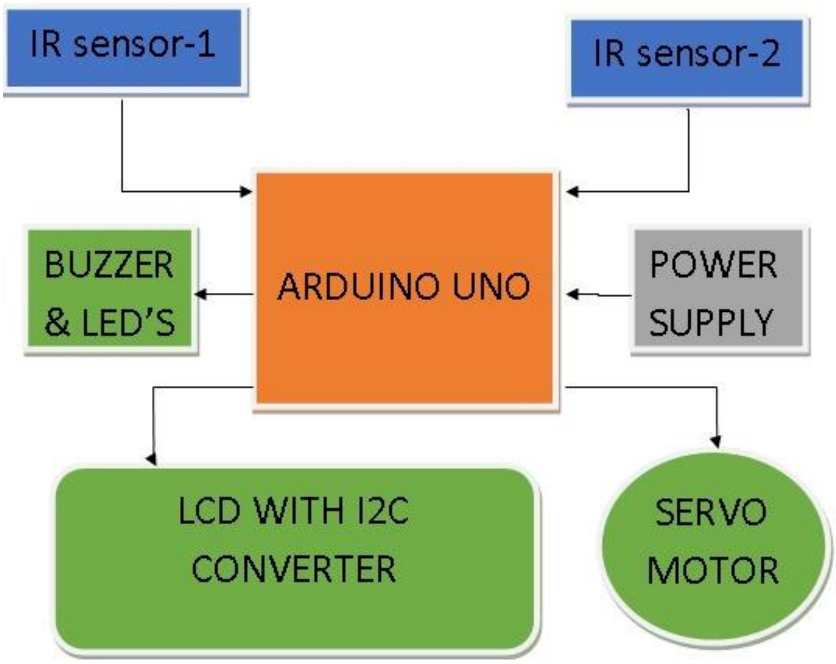

Figure 3.2 Proposed Method

CHAPTER 4

SOFTWARE AND HARDWARE REQUIREMENT

4.1ARDUINO (IDE)

The Arduino integrated development environment (IDE) is a cross- platform application (for Windows, macOS, Linux) that is written in the programming language Java. It is used to write and upload programs to Arduino board.

The source code for the IDE is released under the GNU General Public License, version 2. The Arduino IDE supports the languages C and C++ using special rules of code structuring.[4] The Arduino IDE supplies a software library from the Wiring project, which provides many common input and output procedures. User-written code only requires two basic functions, for starting the sketch and the main program loop, that are compiled and linked with a program stub main() into an executable cyclic executive program with the GNU tool chain, also included with the IDE distribution. The Arduino IDE employs the program argued to convert the executable code into a text file in hexadecimal encoding that is loaded into the Arduino board by a loader program in the board's firmware.

Arduino is an open-source electronics platform based on easy-to-use hardware and software. Arduino boards are able to read inputs - light on a sensor, a finger on a button, or a Twitter message - and turn it into an output - activating a motor, turning on an LED, publishing something online. You can tell your board what to do by sending a set of instructions to the microcontroller on the board.

The Arduino IDE is incredibly minimalistic, yet it provides a near- complete environment for most Arduino-based projects. The top menu bar has the standard options, including “File” (new, load save, etc.), “Edit” (font, copy, paste, etc.), “Sketch” (for compiling and programming), “Tools” (useful options for testing projects), and “Help”. The middle section of the IDE is a simple text editor that where you can enter the program code. The bottom section of the IDE is dedicated to an output window that is used to see the status of the compilation, how much memory has been used, any errors that were found in the program, and various other useful messages.

Projects made using the Arduino are called sketches, and such sketches are usually written in a cut-down version of C++ (a number of C++ features are not included). Because programming a microcontroller is somewhat different from programming a computer, there are a number of device-specific libraries (e.g., changing pin modes, output data on pins, reading analog values, and timers). This sometimes confuses users who think Arduino is programmed in an "Arduino language." However, the Arduino is, in fact, programmed in C++. It just uses unique libraries for the device.

The Arduino Integrated Development Environment - or Arduino Software (IDE) - contains a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions and a series of menus. It connects to the Arduino and Genuine hardware to upload programs and communicate with them.

Programs written using Arduino Software (IDE) are called sketches Figure 4.1 Arduino IDE sketch window where the sketch for the project is coded and compiled.

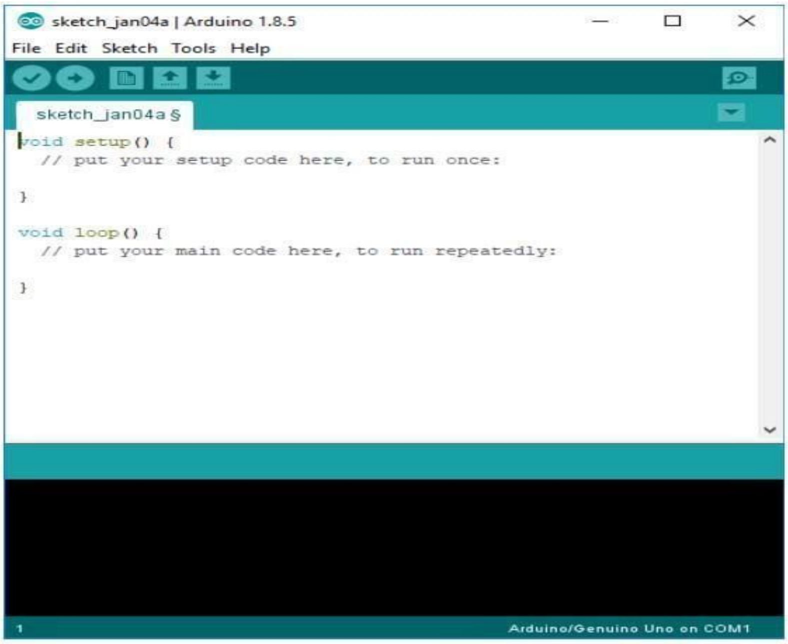

Figure 4.1 Arduino IDE

These sketches are written in the text editor and are saved with the file extension .ino. The editor has features for cutting/pasting and for searching/replacing text. The message area gives feedback while saving and exporting and also displays errors. The console displays text output by the Arduino Software (IDE), including complete error messages and other information. The bottom right hand corner of the window displays the configured board and serial port. The toolbar buttons allow you to verify and upload programs, create, open, and save sketches, and open the serial monitor.

4.1.1 Connecting the Arduino

Connecting an Arduino board to your PC is quite simple. On Windows:

1. Plug in the USB cable - one end to the PC, and one end to the Arduino board.

2. When prompted, select "Browse my computer for driver" and then select the folder to which you extracted your original Arduino IDE download.

3. You may receive an error that the board is not a Microsoft certified device - select “Install anyway.”

4. Your board should now be ready for programming.

When programming your Arduino board, it is important to know what COM port the Arduino is using on your PC. On Windows, navigate to Start-

Devices and Printers, and look for the Arduino. The COM port will be displayed underneath.

Alternatively, the message telling you that the Arduino has been connected successfully in the lower-left hand corner of your screen usually specifies the COM port is it using.

4.1.2 Preparing the Board

Before loading any code to your Arduino board, you must first open the IDE. Double click the Arduino .exe file that you downloaded earlier. A blank program, or "sketch," should open.

The Blink example is the easiest way to test any Arduino board. Within the Arduino window, it can be found under File->Examples->Basics->Blink.

Before the code can be uploaded to your board, two important steps are required.

1. Select your Arduino from the list under Tools->Board. The standard board used in RBE 1001, 2001, and 2002 is the Arduino Mega 2560, so select the "Arduino Mega 2560 or Mega ADK" option in the dropdown.

2. Select the communication port, or COM port, by going to Tools->Serial Port.

If you noted the COM port your Arduino board is using, it should be listed in the dropdown menu. If not, your board has not finished installing or needs to be reconnected.

4.1.3 Loading Code

The upper left of the Arduino window has two buttons: A checkmark to Verify your code, and a right-facing arrow to Upload it. Press the right arrow button to compile and upload the Blink example to your Arduino board.

The black bar at the bottom of the Arduino window is reserved for messages indicating the success or failure of code uploading. A "Completed Successfully" message should appear once the code is done uploading to your board. If an error message appears instead, check that you selected the correct board and COM port in the Tools menu, and check your physical connections.

If uploaded successfully, the LED on your board should blink on/off once every second. Most Arduino boards have an LED prewired to pin 13 is very important that you do not use pins 0 or 1 while loading code. It is recommended that you do not use those pins ever.

Arduino code is loaded over a serial port to the controller. Older models use an FTDI chip which deals with all the USB specifics. Newer models have either a small

AVR that mimics the FTDI chip or a built-in USB-to-serial port on the AVR micro-controller itself.

4.2 ARDUINO UNO

The Arduino UNO is an open-source microcontroller board based on the Microchip ATmega328P microcontroller and developed by Arduino.cc. The board is equipped with sets of digital and analog input/output (I/O) pins that may be

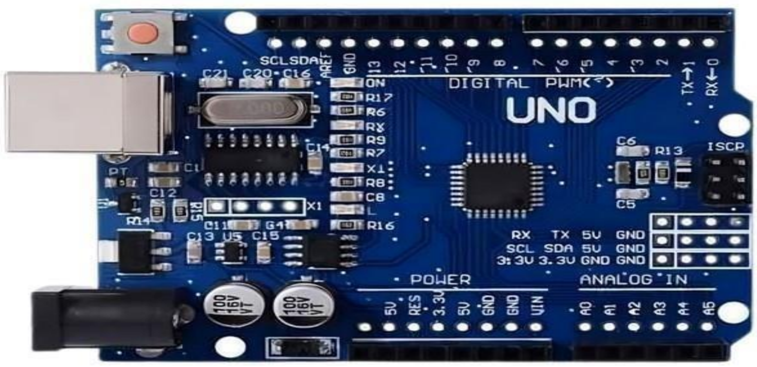

Figure 4.2 Arduino UNO

Interfaced to various expansion boards (shields) and other circuits. The board has 14 Digital pins, 6 Analog pins, and programmable with the Arduino IDE (Integrated Development Environment) via a type B USB cable. It can be powered by a USB cable or by an external 9-volt battery, though it accepts voltages between 7 and 20 volts. It is also similar to the Arduino Nano and Leonardo. The hardware reference design is distributed under a Creative Commons Attribution Share-Alike 2.5 license and is available on the Arduino website. Layout and production files for some versions of the hardware are also available. "Uno" means one in Italian and was chosen to mark the release of Arduino Software (IDE) 1.0. The Uno board and version 1.0 of Arduino Software (IDE) were the reference versions of Arduino, now evolved to newer releases. The Uno board is the first in a series of USB Arduino boards, and the reference model for the Arduino platform Figure 4.2 Top view of the Arduino UNO. The ATmega328 on the Arduino Uno comes preprogrammed with a boot loader that allows uploading new code to it without the use of an external hardware programmer. It communicates using the original STK500 protocol. The Uno also differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it uses the Atmega16U2 (Atmega8U2 up to version R2) programmed as a USB-to-serial converter. The Arduino project started at the Interaction Design Institute Ivrea (IDII) in Ivrea, Italy. At that time, the students used a BASIC Stamp microcontroller at a cost of $100, a considerable expense for many students. In 2003 Hernando Barragán created the development platform Wiring as a Master's thesis project at IDII, under the supervision of Massimo Banzi and Casey Reas, who are known for work on the Processing language. The project goal was to create simple, low- cost tools for creating digital projects by non-engineers. The Wiring platform consisted of a printed circuit board (PCB) with an ATmega168 microcontroller, an

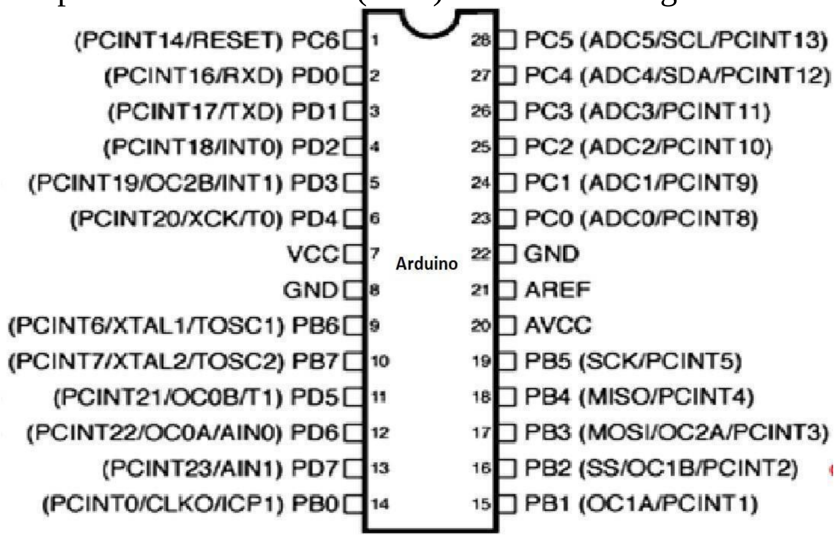

Figure 4.3 ATMEGA328p pin diagram

IDE based on Processing and library functions to easily program the microcontroller Figure 4.3 ATMEGA328p pin configuration diagram. In 2003, Massimo Banzi, with David Mellis, another IDII student, and David Cuartielles, added support for the cheaper ATmega8 microcontroller to Wiring. But instead of continuing the work on Wiring, they forked the project and renamed it Arduino. Early Arduino boards used the FTDI USB-to-serial driver chip and an ATmega168. The Uno differed from all preceding boards by featuring the ATmega328P microcontroller and an ATmega16U2 (Atmega8U2 up to version R2) programmed as a USB-to-serial converter.

4.2.1 Specification

- **Microcontroller:** Microchip ATmega328P
- **Operating Voltage:** 5 Volt
- **Input Voltage:** 7 to 20 Volts
- **Digital I/O Pins:** 14 (of which 6 provide PWM output)
- **Analog Input Pins:** 6
- **DC Current per I/O Pin:** 20 mA
- **DC Current for 3.3V Pin:** 50 mA
- **Flash Memory:** 32 KB of which 0.5 KB used by boot loader
- **SRAM:** 2 KB
- **EEPROM:** 1 KB
- **Clock Speed:** 16 MHz
- **Length:** 68.6 mm
- **Width:** 53.4 mm

- **LED:** There is a built-in LED driven by digital pin 13. When the pin is HIGH value, the LED is on, when the pin is LOW, it's off.
- **VIN:** The input voltage to the Arduino/Genuino board when it's using an external power source (as opposed to 5 volts from the USB connection or other regulated power source). You can supply voltage through this pin, or, if supplying voltage via the power jack, access it through this pin.
- **5V:** This pin outputs a regulated 5V from the regulator on the board. The board can be supplied with power either from the DC power jack (7 - 20V), the USB connector

(5V), or the VIN pin of the board (7-20V). Supplying voltage via the 5V or 3.3V pins bypasses the regulator, and can damage the board.

- **3V3:** A 3.3 volt supply generated by the on-board regulator. Maximum current draw is 50 mA.
- **GND:** Ground pins.
- **IOREF:** This pin on the Arduino/Genuino board provides the voltage reference with which the microcontroller operates. A properly configured shield can read the IOREF pin voltage and select the appropriate power source or enable voltage translators on the outputs to work with the 5V or 3.3V.
- **Reset:** Typically used to add a reset button to shields which block the one on the board.

Table 4.1 Arduino UNO Pinout Configuration

Pin Category	Pin Name	Details
Power	Vin, 3.3V, 5V, GND	Vin: Input voltage to Arduino when using an external power source. 5V: Regulated power supply used to power microcontroller and other components on the board. 3.3V: 3.3V supply generated by on-board voltage regulator. Maximum current draw is 50mA. GND: ground pins.
Reset	Reset	Resets the microcontroller.

Analog Pins	A0 – A5	Used to provide analog input in the range of 0-5V
Input/Output Pins	Digital Pins 0 - 13	Can be used as input or output pins.
Serial	0(Rx), 1(Tx)	Used to receive and transmit TTL serial data.
External Interrupts	2, 3	To trigger an interrupt.
PWM	3, 5, 6, 9, 11	Provides 8-bit PWM output.
SPI	10 (SS), 11 (MOSI), 12 (MISO) and 13 (SCK)	Used for SPI communication.
Inbuilt LED	13	To turn on the inbuilt LED.
TWI	A4 (SDA), A5 (SCA)	Used for TWI communication.

4.2.2 Special Pin Functions

- Each of the 14 digital pins as shown in the Table 4.1 and 6 Analog pins on the Uno can be used as an input or output, using pinMode (), digitalWrite(), and digitalRead() functions.
- They operate at 5 volts.
- Each pin can provide or receive 20 mA as recommended operating condition and has an internal pull-up resistor (disconnected by default) of 20-50k ohm.

- A maximum of 40mA is the value that must not be exceeded on any I/O pin to avoid permanent damage to the microcontroller.
- The Uno has 6 analog inputs, labeled A0 through A5, each of which provide 10 bits of resolution (i.e. 1024 different values).
- By default they measure from ground to 5 volts, though is it possible to change the upper end of their range using the AREF pin and the analogReference() function.

In addition, some pins have specialized functions:

- **UART:** pins 0 (RX) and 1 (TX). Used to receive (RX) and transmit (TX) TTL serial data. These pins are connected to the corresponding pins of the ATmega8U2 USB-to-TTL Serial chip.
- **External Interrupts:** pins 2 and 3. These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value.
- **PWM (Pulse Width Modulation):** 3, 5, 6, 9, 10, and 11 Can provide 8-bit PWM output with the analogWrite () function.
- **SPI (Serial Peripheral Interface):** 10 (SS), 11 (MOSI), 12 (MISO), 13 (SCK). These pins support SPI communication using the SPI library.
- **TWI (Two Wire Interface) / I²C:** A4 or SDA pin and A5 or SCL pin. Support TWI communication using the Wire library.
- **AREF (Analog Reference):** Reference voltage for the analog inputs

4.3 INFRARED SENSOR

An IR (Infrared) sensor is an electronic device that emits and detects infrared radiation in order to sense some aspect of its surroundings. An IR sensor can measure the heat of an object as well as detect motion. Typically, an IR sensor consists of an IR LED and an IR photodiode; the LED emits infrared light, which can reflect back from nearby objects and be detected by the photodiode. The changes in the properties of the received signal, such as its strength or the time it takes to return, allow the sensor to judge distance, presence, or proximity of an object. This functionality makes IR sensors invaluable in various applications such as in robotic obstacle avoidance, line-following vehicles, object detection, and automatic counting systems, among others. They are particularly favored in applications where contactless detection is required. Due to their reliance on infrared radiation, which is invisible to the human eye, IR sensors are usually not affected by ambient light, making them suitable for conditions that require consistent performance regardless of lighting conditions.

IR sensor is an electronic device, that emits the light in order to sense some object of the surroundings Figure 4.4 Infrared sensor isometric view. An IR sensor can measure the heat of an object as well as detects the motion. Usually, in the infrared spectrum, all the objects radiate some form of thermal radiation. These types of radiations are invisible to our eyes, but infrared sensor can detect these radiations.

The emitter is simply an IR LED (Light Emitting Diode) and the detector is simply an IR photodiode. Photodiode is sensitive to IR light of the same wavelength which is emitted by the IR LED. When IR light falls on the photodiode, the resistances and the output voltages will change in proportion to the magnitude of the IR light received.

There are five basic elements used in a typical infrared detection system: an infrared source, a transmission medium, optical component, infrared detectors or

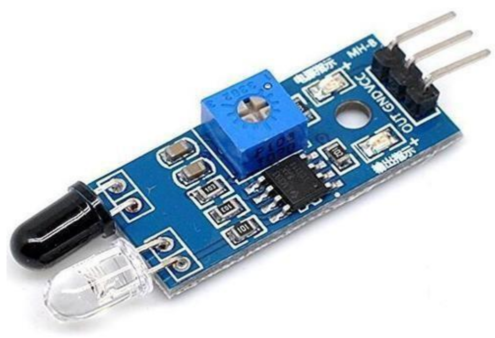

Figure 4.4 Infrared Sensor

receivers and signal processing. Infrared lasers and Infrared LEDs of specific wavelength used as infrared sources.

The three main types of media used for infrared transmission are vacuum, atmosphere and optical fibres. Optical components are used to focus the infrared radiation or to limit the spectral response.

4.3.1 Types of IR Sensor

There are two types of IR sensors are available and they are,

- Active Infrared Sensor
- Passive Infrared Sensor

4.3.2 Active Infrared Sensor

Active infrared sensors consist of two elements: infrared source and infrared detector. Infrared sources include the LED or infrared laser diode. Infrared detectors include photodiodes or phototransistors. The energy emitted by the infrared source is reflected by an object and falls on the infrared detector.

4.3.3 Passive Infrared Sensor

Passive infrared sensors are basically Infrared detectors. Passive infrared sensors do not use any infrared source and detector. They are of two types: quantum and thermal. Thermal infrared sensors use infrared energy as the source of heat. Thermocouples, pyroelectric detectors and bolometers are the common types of thermal infrared detectors. Quantum type infrared sensors offer higher detection performance. It is faster than thermal type infrared detectors. The photo sensitivity of quantum type detectors is wavelength dependent.

4.3.4 IR Sensor Working Principle

There are different types of infrared transmitters depending on their wavelengths, output power and response time Figure 4.7 Working of IR sensor. An IR sensor consists of an IR LED and an IR Photodiode, together they are called as Photocoupler or Optocoupler.

4.3.5 IR Transmitter and Receiver

Infrared Transmitter is a light emitting diode (LED) which emits infrared radiations called as IR LED's Figure 4.5 IR transmitter. Even though an IR LED looks like a normal LED, the radiation emitted by it is invisible to the human eye.

The picture of an Infrared LED is shown below.

Figure 4.5 IR Transmitter

Infrared receivers or infrared sensors detect the radiation from an IR transmitter. IR receivers come in the form of photodiodes and phototransistors Figure 4.6 IR receiver. Infrared Photodiodes are different from normal photo diodes as they detect only infrared radiation. Below image shows the picture of an IR receiver or a photodiode,

Figure 4.6 IR Receiver

Different types of IR receivers exist based on the wavelength, voltage, package, etc. When used in an infrared transmitter – receiver combination, the wavelength of the receiver should match with that of the transmitter.

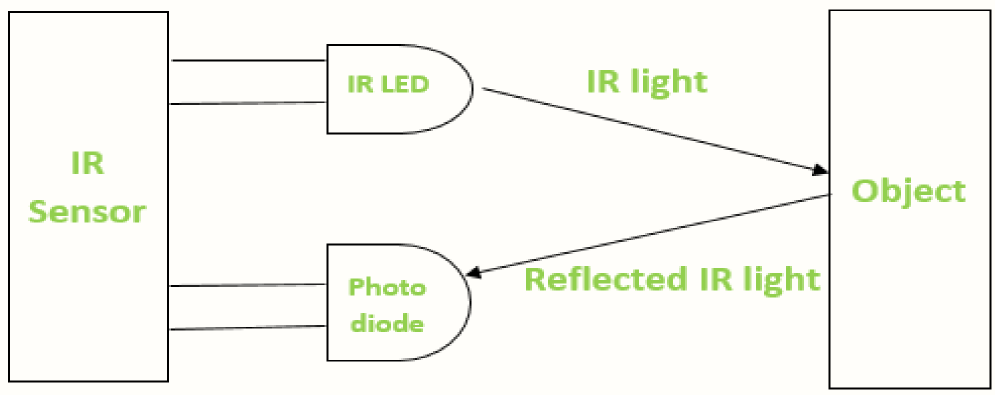

Figure 4.7 Working of IR Sensnor

The emitter is an IR LED and the detector is an IR photodiode. The IR photodiode is sensitive to the IR light emitted by an IR LED. The photo-diode’s resistance and output voltage change in proportion to the IR light received. This is the underlying working principle of the IR sensor. When the IR transmitter emits radiation, it reaches the object and some of the radiation reflects back to the IR receiver. Based on the intensity of the reception by the IR receiver, the output of the sensor defines.

4.4 SERVO MOTOR

A servo motor is a type of rotary actuator designed for precision control of angular or linear position, velocity, and acceleration. It typically consists of a motor coupled to a sensor for position feedback, integrated with a control circuit. Servo motors are distinct in their ability to control motion precisely; they use feedback from the position sensor to adjust the rotational position of the motor shaft by sending varying pulse widths via a control wire Figure 4.8 Servo motor. This allows the servo to be set to any position within its range of operation, with control signals that dictate the amount of movement rather than continuous rotation, which distinguishes them from other types of motors that rotate indefinitely. Servos are commonly used in applications such as robotics, remote-controlled vehicles, and anywhere precise movement is required. They come in various sizes and specifications to suit different power and precision requirements, from small units for hobbyist projects to larger industrial-grade models designed for more robust applications. The ability to operate under a closed-loop mechanism (feedback control) allows servos to maintain stable and accurate positioning even under varying load conditions.

A servo motor is a type of motor that can rotate with great precision. Normally this type of motor consists of a control circuit that provides feedback on the current position of the motor shaft, this feedback allows the servo motors to rotate with great precision. If you want to rotate an object at some specific angles or distance, then you use a servo motor. It is just made up of a simple motor which runs through a servo mechanism. If motor is powered by a DC power supply then it is called DC servo

Figure 4.8 Servo Motor

motor, and if it is AC-powered motor then it is called AC servo motor. For this tutorial, we will be discussing only about the DC servo motor working. Apart from these major classifications, there are many other types of servo motors based on the type of gear arrangement and operating characteristics. A servo motor usually comes with a gear arrangement that allows us to get a very high torque servo motor in small and lightweight packages. Due to these features, they are being used in many applications like toy car, RC helicopters and planes, Robotics, etc.

Servo motors are rated in kg/cm (kilogram per centimeter) most hobby servo motors are rated at 3kg/cm or 6kg/cm or 12kg/cm. This kg/cm tells you how much weight your servo motor can lift at a particular distance. For example: A 6kg/cm Servo motor should be able to lift 6kg if the load is suspended 1cm away from the motors shaft, the greater the distance the lesser the weight carrying capacity. The position of a servo motor is decided by electrical pulse and its circuitry is placed beside the motor.

4.4.1 Servo Motor Working Mechanism

It consists of three parts:

1. Controlled device

2. Output sensor

3. Feedback system

It is a closed-loop system where it uses a positive feedback system to control motion and the final position of the shaft. Here the device is controlled by a feedback signal generated by comparing output signal and reference input signal.

Here reference input signal is compared to the reference output signal and the third signal is produced by the feedback system. And this third signal acts as an input signal to the control the device. This signal is present as long as the feedback signal is generated or there is a difference between the reference input signal and reference output signal. So, the main task of servomechanism is to maintain the output of a system at the desired value at presence of noises.

4.4.2 Servo Motor Working Principle

A servo consists of a Motor (DC or AC), a potentiometer, gear assembly, and a controlling circuit. First of all, we use gear assembly to reduce RPM and to increase torque of the motor. Say at initial position of servo motor shaft, the position of the potentiometer knob is such that there is no electrical signal generated at the output port of the potentiometer. Now an electrical signal is given to another input terminal of the error detector amplifier. Now the difference between these two signals, one comes from the potentiometer and another comes from other sources, will be processed in a feedback mechanism and output will be provided in terms of error signal. This error signal acts as the input for motor and motor starts rotating. Now motor shaft is connected with the potentiometer and as the motor rotates so the potentiometer and it will generate a signal. So as the potentiometer's angular position changes, its output feedback signal changes. After sometime the position of potentiometer reaches at a position that the output of potentiometer is same as external signal provided. At this condition, there will be no output signal from the amplifier to the motor input as there is no difference between external applied signal and the signal generated at potentiometer, and in this situation motor stops rotating.

4.4.3 Interfacing Servo Motor with Microcontrollers

Interfacing hobby Servo motors like s90 servo motor with MCU is very easy. Servos have three wires coming out of them. Out of which two will be used for Supply (positive and negative) and one will be used for the signal that is to be sent from the MCU. An MG995 Metal Gear Servo Motor which is most commonly used for RC cars humanoid bots etc. The picture of MG995 is shown below:

The color coding of your servo motor might differ hence check for your respective datasheet Figure 4.9 Servo motor pin diagram.

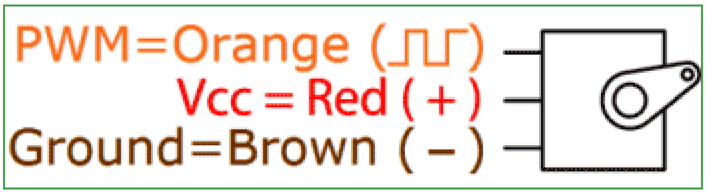

Figure 4.9 Servo Motor Pin Diagram

All servo motors work directly with your +5V supply rails but we have to be careful on the amount of current the motor would consume if you are planning to use more than two servo motors a proper servo shield should be designed.

4.4.4 Controlling Servo Motor

All motors have three wires coming out of them. Out of which two will be used for Supply (positive and negative) and one will be used for the signal that is to be sent from the MCU.

Servo motor is controlled by PWM (Pulse with Modulation) which is provided by the control wires. There is a minimum pulse, a maximum pulse and a repetition rate. Servo motor can turn 90 degree from either direction form its neutral position. The servo motor expects to see a pulse every 20 milliseconds (ms) and the length of the pulse will determine how far the motor turns. For example, a 1.5ms pulse will make the motor turn to the 90° position, such as if pulse is shorter than 1.5ms shaft moves to 0° and if it is longer than 1.5ms than it will turn the servo to 180° Figure 4.10 Servo motor rotation movement.

Servo motor works on PWM (Pulse width modulation) principle, means its angle of rotation is controlled by the duration of applied pulse to its Control PIN. Basically servo motor is made up of DC motor which is controlled by a variable resistor (potentiometer) and some gears. High speed force of DC motor is converted into torque by Gears. We know that WORK= FORCE X DISTANCE, in DC motor Force is less and distance (speed) is high and in Servo, force is High and distance is less. The potentiometer is connected to the output shaft of the Servo, to calculate the angle and stop the DC motor on the required angle.

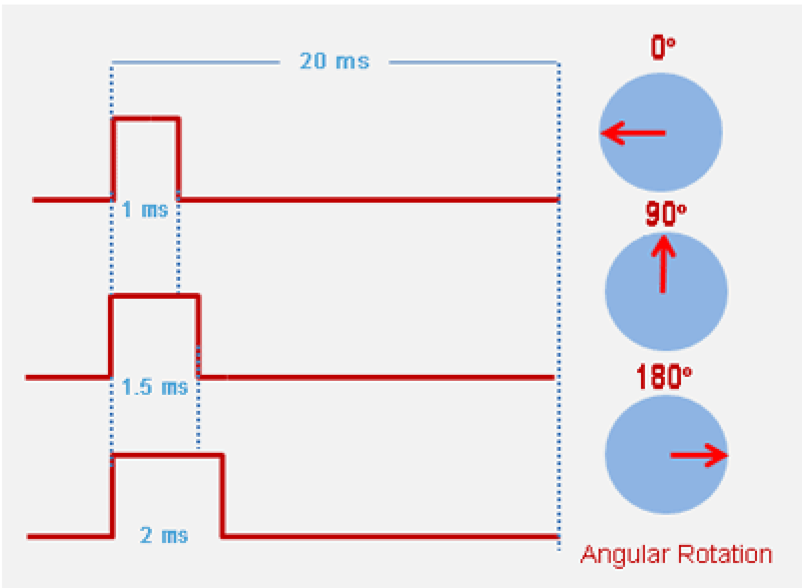

Figure 4.10 Servo Motor Rotation Movement

Servo motor can be rotated from 0 to 180 degrees, but it can go up to 210 degrees, depending on the manufacturing. This degree of rotation can be controlled by applying the Electrical Pulse of proper width, to its Control pin. Servo checks the pulse in every 20 milliseconds. The pulse of 1 ms (1 millisecond) width can rotate the servo to 0 degrees, 1.5ms can rotate to 90 degrees (neutral position) and 2 ms pulse can rotate it to 180 degree.

All servo motors work directly with your +5V supply rails but we have to be careful about the amount of current the motor would consume if you are planning to use more than two servo motors a proper servo shield should be designed.

4.5 LIQUID CRYSTAL DISPLAY (LCD)

A liquid crystal display (LCD) is a flat panel display, electronic visual display, or video display that uses the light modulating properties of liquid crystals. Liquid crystals do not emit light directly. It pinout configuration shown in Table 4.2 LCDs are available to display arbitrary images (as in a general-purpose computer display) or fixed images which can be displayed or hidden, such as preset words, digits, and 7- segment displays as in a digital clock Figure 4.11 LCD display. They use the same basic technology, except that arbitrary images are made up of a large number of small pixels, while other displays have larger elements. An LCD is a small low cost display. It is easy to interface with a micro-controller because of an embedded controller (the black blob on the back of the board). This controller is standard across many displays (HD 44780) which means

Table 4.2 LCD Pinout Configuration

Pin No	Function	Name
1	Ground (0V)	Ground
2	Supply voltage; 5V (4.7V – 5.3V)	Vcc
3	Contrast adjustment; through a variable resistor	VEE

4	Selects command register when low; and data register when high	Register Select
5	Low to write to the register; High to read from the register	Read/write
7	8-bit data pins	D0
8		D1
9		D2
10		D3
11		D4
12		D5
13		D6
14		D7
15	Backlight VCC (5V)	Led+
16	Backlight Ground (0V)	Led-

Figure 4.11 LCD Display

many micro-controllers (including the Arduino) have libraries that make displaying messages as easy as a single line of code Figure 4.12 LCD display pin diagram.

LCD's are used in a wide range of applications including computer monitors, televisions, instrument panels, aircraft cockpit displays, and signage. They are common in consumer devices such as video players, gaming devices, clocks, watches,

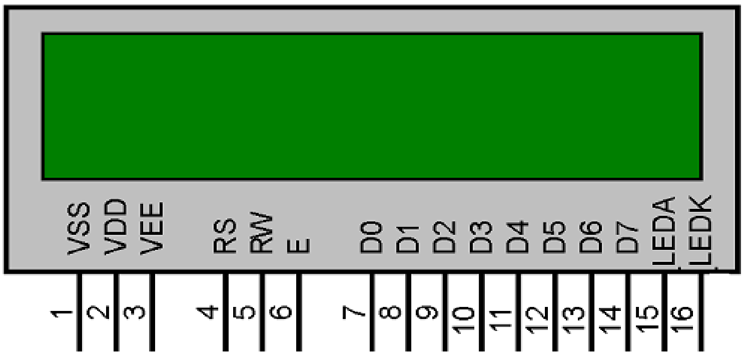

Figure 4.12 LCD Display Pin Diagram

calculators, and telephones, and have replaced cathode ray tube (CRT) displays in most applications. They are available in a wider range of screen sizes than CRT and plasma displays, and since they do not use phosphors, they do not suffer image burn-in. LCDs are, however, susceptible to image persistence.

4.5.1 Different Types of LCD

There are mainly four types of LCD are available.

1. Twisted Nematic (TN)

Which are cheap but have fast response times. TN screens, on the other hand, have low contrast ratios, viewing angles, and color contrasts. The use of TN LCDs in many types of displays across industries has resulted in their widespread manufacture.

2. Panel Switching Displays (IPS Panels)

When compared to TN LCDs, In Panel Switching displays (IPS Panels) have significantly higher contrast ratios, viewing angles, and color contrast. When compared to TN LCDs, In Panel Switching displays provide superior picture quality, bright color precision, and difference.

3. Vertical Alignment Panels (VA Panels)

Vertical Alignment Panels (VA Panels) are regarded as a grade intermediate between TN and IPS displays. Vertical alignment panels are seen to be a good compromise between in-plane switching panels and twisted nematic technology. When compared to TN-type displays, this type of panel has superior quality color reproduction as well as the best viewing angles.

4. Advanced Fringe Field Switching (AFFS)

A top performer in the color reproduction range when compared to IPS displays. AFFS LCD is a top performer with a wide range of color reproduction options. These monitors produce high-quality images. These displays are most typically used in high-tech applications such as viable airplane cockpits.

4.5.2 Working of LCD

The premise underlying LCDs is that liquid crystals are used to flip pixels on and off to expose a specific color. When an electrical current is provided to a liquid crystal molecule, the molecule tends to untwist. This produces a shift in the angle of the top polarizing filter, as well as the angle of light traveling through the molecule of the polarized glass. As a result, a little light is permitted to let the polarized glass through an individual area of the LCD.

As a result, in comparison to other places, this one will appear dark. LCDs work on the premise of blocking light rather than emitting it. When the LCDs are built, a mirror is installed on the backside. The electrode plane, which is kept on top of the device, is made of indium-tin-oxide. A polarized glass with a polarizing coating is also included on the device’s bottom.

The entire region of the LCD must be contained with the use of a common electrode, and the liquid crystal matter must be above it. Then, on top, another polarizing film, and on the bottom, in the shape of a rectangle, the second piece of glass with an electrode. However, ensure that both parts are at the correct angles.

When there is no current, light flows through the front of the LCD, reflecting and bouncing back with the help of a mirror. In front of the light is a screen composed of red, green, and blue pixels. To reveal a certain hue or keep a pixel dark, liquid crystals work by turning on or off a filter.

4.6 I2C CONVERTER

An I2C converter, or I2C interface adapter, is a device that facilitates communication between a microcontroller and peripherals that use the I2C (Inter-Integrated Circuit) protocol, particularly when there is a need to convert between different voltage levels or interfaces. I2C is a serial communication protocol that uses only two wires (SDA for data and SCL for clock), making it highly efficient for connecting multiple slave devices to a master device over short distances Figure 4.13 I2C converter. An I2C converter becomes essential when interfacing devices that operate at incompatible voltage levels. For example, if a microcontroller operates at 3.3V and a sensor operates at 5V, an I2C converter can safely bridge these devices,

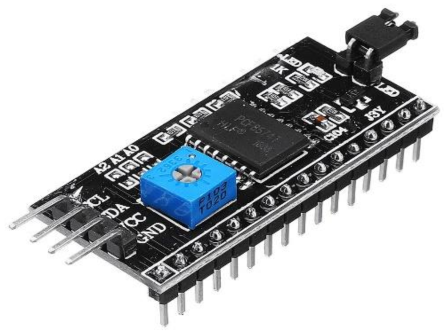

Figure 4.13 I2C Converter

ensuring proper logic level conversion without risk of damaging the components. Additionally, these converters can expand the number of devices that can be connected to a single microcontroller by providing additional I2C bus ports. This is particularly useful in complex systems where many sensors, displays, or other peripherals need to communicate with a central processor. The use of an I2C converter simplifies the design and implementation of multi-device communication, maintaining signal integrity and facilitating scalable and efficient designs.

4.7 BUZZER

There are many ways to communicate between the user and a product. One of the best ways is audio communication using a buzzer IC. So during the design process, understanding some technologies with configurations is very helpful. So, this article discusses an overview of an audio signaling device like a beeper or a buzzer and its working with applications Figure 4.14 Buzzer .

An audio signaling device like a beeper or buzzer may be electromechanical or piezoelectric or mechanical type. The main function of this is to convert the signal from audio to sound. Generally, it is powered through DC voltage and used in timers, alarm devices, printers, alarms, computers, etc. Based on the various designs, it can generate different sounds like alarm, music, bell & siren.

The pin configuration of the buzzer is shown below. It includes two pins namely positive and negative. The positive terminal of this is represented with the '+' symbol

Figure 4.14 Buzzer

or a longer terminal. This terminal is powered through 6Volts whereas the negative terminal is represented with the '-'symbol or short terminal and it is connected to the GND terminal.

4.7.1 Specifications

The specifications of the buzzer include the following.

- Color is black

- The frequency range is 3,300Hz
- Operating Temperature ranges from – 20° C to +60°C
- Operating voltage ranges from 3V to 24V DC
- The sound pressure level is 85dBA or 10cm
- The supply current is below 15mA

4.7.2 Types Of Buzzer

A buzzer is available in different types which include the following.

- Piezoelectric
- Electromagnetic
- Mechanical
- Electromechanical
- Magnetic

1. Piezoelectric

As the name suggests, the piezoelectric type uses the piezoelectric ceramic's piezoelectric effect & pulse current to make the metal plate vibrate & generate sound. This kind of buzzer is made with a resonance box, multi resonator, piezoelectric plate, housing, impedance matcher, etc. Some of the buzzers are also designed with LEDs.

The multi resonator of this mainly includes ICs and transistors. Once the supply is given to this resonator, it will oscillate and generates an audio signal with 1.5 to 2.kHz. The impedance matcher will force the piezoelectric plate to produce sound.

2. Electromagnetic

This type of buzzer is made with a magnet, solenoid coil, oscillator, housing, vibration diaphragm, and magnet. Once the power supply is given, the oscillator which produces the audio signal current will supply throughout the solenoid coil to generate a magnetic field.

Sometimes, the vibration diaphragm will vibrate & generates sound under the magnet & solenoid coil interaction. The frequency range of this ranges from 2 kHz to 4kHz.

3. Mechanical

These types of buzzers are subtypes of electromagnetic, so the components used in this type are also similar. But the main difference is that the vibrating buzzer is placed on the outside instead of the inside.

4. Electromechanical

The designing of these types of buzzers can be done with a bare metal disc & an electromagnet. The working principle of this is similar to magnetic and electromagnetic. It generates sound throughout the disc movement & magnetism.

5. Magnetic

Like a piezo type, magnetic is also used to generate a sound but they are different due to core functionality. The magnetic type is more fixed as compared to the piezo type because they work through a magnetic field.

Magnetic buzzers utilize an electric charge instead of depending on piezo materials to generate a magnetic field, after that it permits another element of the buzzer to vibrate & generate sound.

The applications of magnetic buzzers are similar to the piezo type in household devices, alarms such as watches, clocks & keyboards.

4.7.3 Working Principle

The working principle of a buzzer depends on the theory that, once the voltage is given across a piezoelectric material, then a pressure difference is produced. A piezo type includes piezo crystals among two conductors.

Once a potential disparity is given across these crystals, then they thrust one conductor & drag the additional conductor through their internal property. So this continuous action will produce a sharp sound signal.

4.7.4 Mounting Configurations

The mounting configurations of buzzers include the following.

- Panel Mount
- Wire Leads
- Screw Terminals
- Through Hole
- Spring Contact
- Surface Mount

A buzzer is an efficient component to include the features of sound in our system or project. It is an extremely small & solid two-pin device thus it can be simply utilized on breadboard or PCB. So in most applications, this component is widely used.

There are two kinds of buzzers commonly available like simple and readymade. Once a simple type is power-driven then it will generate a beep sound continuously. A readymade type looks heavier & generates a Beep. Beep. Beep. This sound is because of the internal oscillating circuit within it.

This buzzer uses a DC power supply that ranges from 4V – 9V. To operate this, a 9V battery is used but it is suggested to utilize a regulated +5V/+6V DC supply. Generally, it is connected through a switching circuit to switch ON/OFF the buzzer at the necessary time interval.

The circuit diagram of the water level indicator using the buzzer is shown below. This circuit is used to sense or detect the water level within the tank or washing machine or pool, etc. This circuit is very simple to design using few components such as a transistor, buzzer, 300K variable resistor, and power supply or 9V battery.

Once the two probes of the circuit are placed in the tank, it detects the level of water. Once the water level exceeds the fixed level, then it generates a beep sound through a buzzer connected to the circuit. This circuit uses a BC547B NPN transistor however we can also use any general-purpose transistor instead of using 2N3904/2N2222.

This water level sensor circuit working is very simple and the transistor used within the circuit works as a switch. Once the two probes notice the water level within the tank, then the transistor turns ON & the voltage begins flowing throughout the transistor to trigger the buzzer.

4.8 LED

Figure 4.15 LED

LED is a semiconductor P-N junction diode. Mostly it is made up of GaAsP, and for the high bright LEDs GaAlAs is used. When a diode is switched on, the electrons from the N-region moves towards the P-region and combine with the holes; finally, the form of light energy is released Figure 4.15 LED. The color of the LED is determined by the energy gap of the semiconductor. Most of the LEDs work between 1.5 to 2V – but, bright LEDs require 3V.

There are 8 parameters to consider in LEDs (light emitting diodes); they are, luminous flux, luminous intensity, luminous efficiency, forward voltage, forward current, viewing angle, energy level and wattage of LED. Depending on these parameters, various LEDs are available in the market today that varies in color, size, rating, and so on, and even the LED TVs are also available.

4.8.1 Different Types Of LED's

LEDs are classified into several types, but only a few of them are explained below.

- LED stripes
- Miniature LEDs
- High-power LED
- Application Specific LED

1. Miniature LED's

Figure 4.16 Miniature LED's

In our day-to-day life, these LED’s are used as indicators in Television sets, mobile phones, model railway layouts, compact electrical equipments, etc. Miniature LED’s are available in the market with a standard size and shape Figure 4.16 Miniature LED’s. These LED’s have less than 3mm diameter, they can come with ready to fit mode with that they can be directly mounted on the circuit boards. These LED’s don’t need support of any additional cooling systems. In the range of 5v and 12v, different companies manufacture these LED’s.

2. LED Stripes

These LED stripes consist of high-powered LED’s that are placed on a thin flexible circuit board and backside of the strip is coated with an adhesive material Figure 4.17 LED’s stripes. Once the power is applied to the LED strip, the owl length of the strip is illuminated producing a forward light. These stripes are inexpensive and easy to install.

Figure 4.17 LED’S Stripes

Different types of LED strip lights include:

- Digital RGB LED strip
- Rhythm following flashing lights
- Flexible LED strip
- Waterproof SMD LED strip
- Decorative blue-colored self-adhesive LED strip
- Decorative Red-colored self-adhesive LED strip

- Decorative White-colored self-adhesive LED strip
- Hit lights red flexible ribbon LED strip
- ACE gold LED strip light
- Multicolor five-meter waterproof flexible LED light strip
- Philips Linea LED light strip
- Philips Lines flexible LED strip
- Hit lights weather proof green flexible ribbon LED strip light

3. High-Power LED's

High-power LED's come in different sizes and shapes with a very high output.

Figure 4.18 High Power LED's

These LEDs have heat dissipation so they need to be mounted along with a cooling system (heat sinks), and they can run over 60,000 hours Figure 4.18 High power LED's. High-power LEDs are used as LED street lights, table lamp, home appliances, indoor & outdoor lightings, etc.

4. Application Specific LED

As the name indicates these are manufactured for a particular application alone. These applications include digital display boards in various annunciation systems, digital bill boards, bi color and tri-color LEDs. A bicolor LED consists of two diodes mounted on a single frame with two pins, in which one pin is anode or cathode. At different times, this LED can produce two colors while it is in a forward bias or reverse bias condition Figure 4.19 LED display. Similar to a bicolor diode, a tri color LED consists of two diodes mounted on a single frame, but with three pins.

4.8.2 LED Applications

Figure 4.19 LED Display

1. LED for Lighting Applications

From the last few years LED lighting systems have become very popular among various applications, such as street lightings, traffic signals, exit signs displays, etc. All the LED lighting systems are not the same, but vary with the diverse parameters and configurations. These LED systems offer tremendous energy, maintenance-free disposition, saves electrical energy and come with a longer life span. Some of the applications of LED lighting systems are as follows:

- LED in offices
- LED in hospitals
- LED for outdoor spaces
- LED in health care
- LED in Retail

2. Display Elements

- LEDs are used in active display, unlike the LCD full-color display, and also in the daytime programmable displays for advertisements.
- LEDs are used in indicators, such as 7-segment array to generate alpha numerical characters.

- Used in automobile break lights and traffic signals.

3. Communication

- Laser diodes are used in long distance communications.
- LAN (local area network)

4.Opto Isolators

- LED as light emitter provides very high degree of isolation in opto isolators.
- In some medical instruments or devices, such as the electrocardiograph amplifiers, during medical treatment very high degree of isolation is need to ensure patient safety, so these LEDs do this job perfectly.

These are the different types of LEDs and their applications. It is our suggestion on behalf of the energy conservation with a social responsibility that please use LEDs for energy efficient lighting in your homes, discotheque light stroboscopic flasher, road ways of your premises and offices, which give better lighting at low cost. And, also please share your views on this article in the comment section.

Photo Credits

- Different types of LEDs by calce

4.9 JUMPER WIRES

Figure 4.20 Jumper Wire

Jumper wires are essential components in electronics and prototyping, serving as flexible connectors to establish electrical connections between various components on a breadboard or between different parts of a circuit Figure 4.20 Jumper Wire. Typically made from flexible, insulated wire with metal pins or connectors at each end, jumper wires allow for quick and temporary connections without the need for soldering.

They come in various lengths, colors, and types, including male-to-male, male-to-female, and female-to-female configurations, offering versatility in connecting different types of components. Jumper wires are widely used in prototyping, testing, and experimenting with electronic circuits, enabling rapid iteration and modification. Their flexibility and ease of use make them indispensable tools for hobbyists, students, and professionals alike in the field of electronics and electrical engineering.

4.10 BATTERIES (LITHION ION BATTERIES)

Batteries are portable energy storage devices that convert chemical energy into electrical energy through a chemical reaction. They are fundamental in powering a wide array of electronic devices, from small gadgets like remote controls to larger systems like electric vehicles. Batteries typically consist of one or more electrochemical cells, each containing two electrodes—an anode and a cathode—separated by an electrolyte. During discharge, electrons flow from the negative terminal (anode) to the positive terminal (cathode) through an external circuit, generating an electric current. This process is reversed during charging. Batteries come in various chemistries, each with its own set of characteristics regarding energy density, voltage, cycle life, and environmental impact. Common types include alkaline, lithium-ion, nickel-metal hydride, and lead-acid batteries. The choice of battery depends on factors such as the intended application, desired lifespan, and environmental considerations. Advances in battery technology continue to drive innovations in electronics, transportation, and renewable energy storage, with ongoing efforts focused on improving energy density, safety, and sustainability.

4.10.1 Working Principle of Lithium-Ion Batteries

Figure 4.21 Battery

Basic Structure: Lithium ion is a rechargeable battery that is made up of one or more cells (a cell is a power generating compartment of the battery), and each cell has the following essential components, namely- an anode, a cathode, a separator, an electrolyte and two current collectors a positive and negative Figure 4.21 Battery. The positive electrode is made of lithium cobalt oxide ($LiCoO2$) or Lithium iron phosphate ($LiFePO4$). The negative electrode is made up of carbon (graphite).

The general working of a LIB is as follows:

- Lithium is stored in anode and cathode.
- The electrolyte carries the positively charged Lithium ion from the cathode to the anode and vice versa through a separator.
- Free electrons are created in the anode due to the movement of lithium ions.
- This, in turn, creates a charge at the positive current collector.
- The electric current then flows through a device, for example, a cell phone, to the negative collector.
- The separator prevents the flow of current inside the battery.

Charge and Discharge: During the discharging of the battery, the anode releases lithium ions to the cathode, which generates an electron flow from one side to the other, and during this process, an electric current is provided Figure 4.22 Battery charge and discharge.

The opposite happens when a device is connected and the lithium ions are released by the cathode and received by the anode; this is precisely how a lithium-ion battery works.

4.10.2 Types of Lithium-Ion Batteries

The lithium-ion batteries are classified on the basis of active materials used in their chemistry. Every type of lithium-ion battery has its own benefits and drawbacks. Basically, there are 6 types of lithium-ion batteries available in the market, they are:

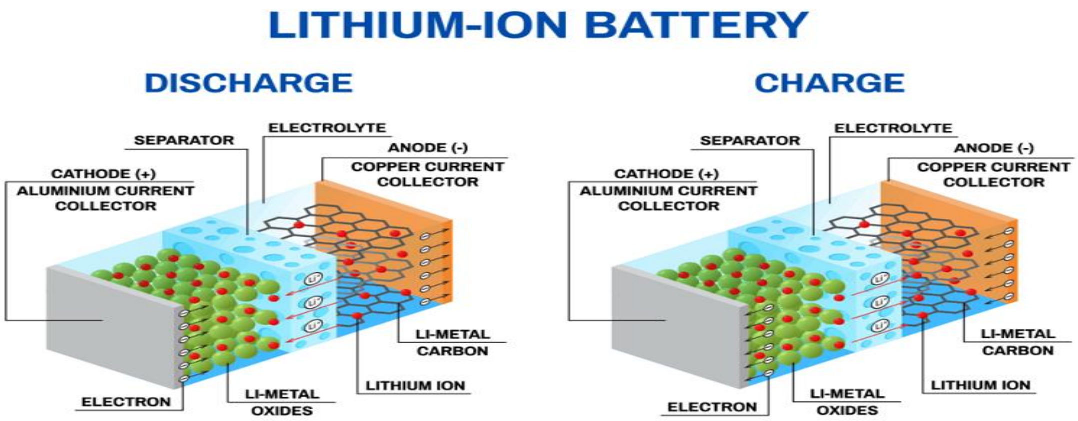

Figure 4.22 Battery Charge and Discharge

1.Lithium iron Phosphate (LiFePO4) or LFP Batteries

- Phosphate is used as the cathode, and graphite as an anode. LFP delivers good thermal stability and performance.
- Uses: LFPs are the most common Lithium-ion batteries used to replace conventional lead acid batteries.
- Benefits: Safety, durability and long-life cycle.

- Drawbacks: Performance suffers in low temperatures, and they also have a low specific energy.

2. Lithium Cobalt Oxide (LCO)

These batteries have high specific energy but low specific power.

- Uses: Small portable electronic items such as mobile phones, laptops, cameras, etc.
- Benefits: LCO batteries deliver power over a long period of time due to high specific energy.
- Drawbacks: Costly, shorter life span, cannot be used for high load applications.

3.Lithium Magnesium Oxide (LMO)

LMOs use MgO2 as the cathode material, thus improving ion flow.

- Uses: Portable power tools, electric and hybrid vehicles, and medical instruments.
- Benefits: Quick charging, high current delivery, better thermal stability, and safety.
- Drawbacks: Short lifespan is the biggest drawback of the LMO.

4.Lithium Nickel Manganese Cobalt Oxide (NMC)

The combination of Nickel, Manganese and Cobalt yields a stable chemistry with high specific energy.

- Uses: Power tools, electric powertrains for e-bikes and some electric vehicles.
- Benefits: High energy density, longer lifecycle and lower cost.
- Drawbacks: Lower voltage output than Cobalt-based batteries.

5.Lithium Nickel Cobalt Aluminium Oxide (NCA)

Can deliver a high amount of current for an extended time.

- Uses: Most popular in the Electric Vehicle market, e.g. Tesla Cars.
- Benefits: High energy with a decent lifespan and can perform in high-load applications.
- Drawbacks: NCA batteries are expensive and comparatively less safe

6.Lithium Titanate/ Lithium Titanium Oxide (LTO)

All the above-discussed battery types have different cathode materials, but the LTOs use 'lithium titanate' as an anode, whereas LMO or NMC is used as a cathode.

- Uses: Electric vehicles, charging stations, UPS, wind and solar energy storage, street lights, military equipment, aerospace, and telecommunication systems.
- Benefits: Fast charging, wide operating temperatures, long lifespan, very safe.
- Drawbacks: NCA batteries are expensive and comparatively less safe.

CHAPTER 5

RESULT AND DISCUSSION

The result of the Railway Gate Controller using Arduino Uno, LCD display with I2C converter, IR sensor, servo motor, LED, and buzzer demonstrates a highly efficient and versatile system for managing railway level crossings. The integration of Arduino Uno as the central processing unit allows for seamless control and coordination of various components, ensuring smooth operation of the gate system.

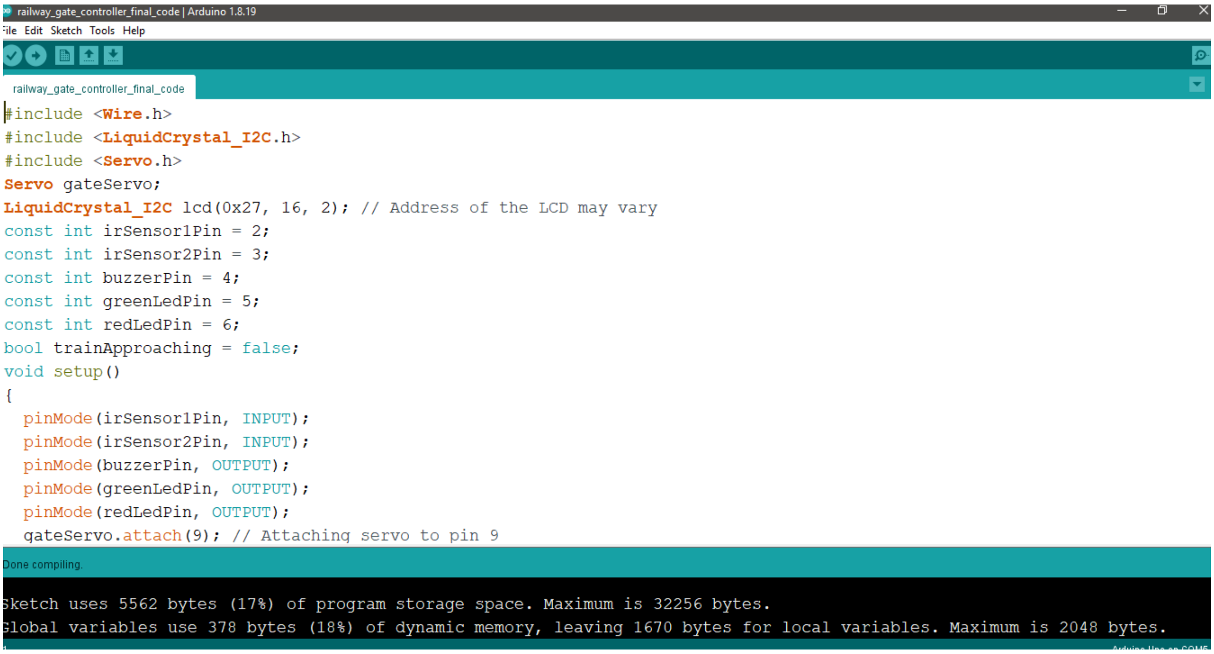

Figure 5.1 Simulation Ouput 1

The LCD display, coupled with the I2C converter, provides clear and concise visual feedback, displaying essential information such as train schedules, gate status, and safety messages. This user-friendly interface enhances communication and situational awareness for both operators and nearby individuals, contributing to overall safety and efficiency.

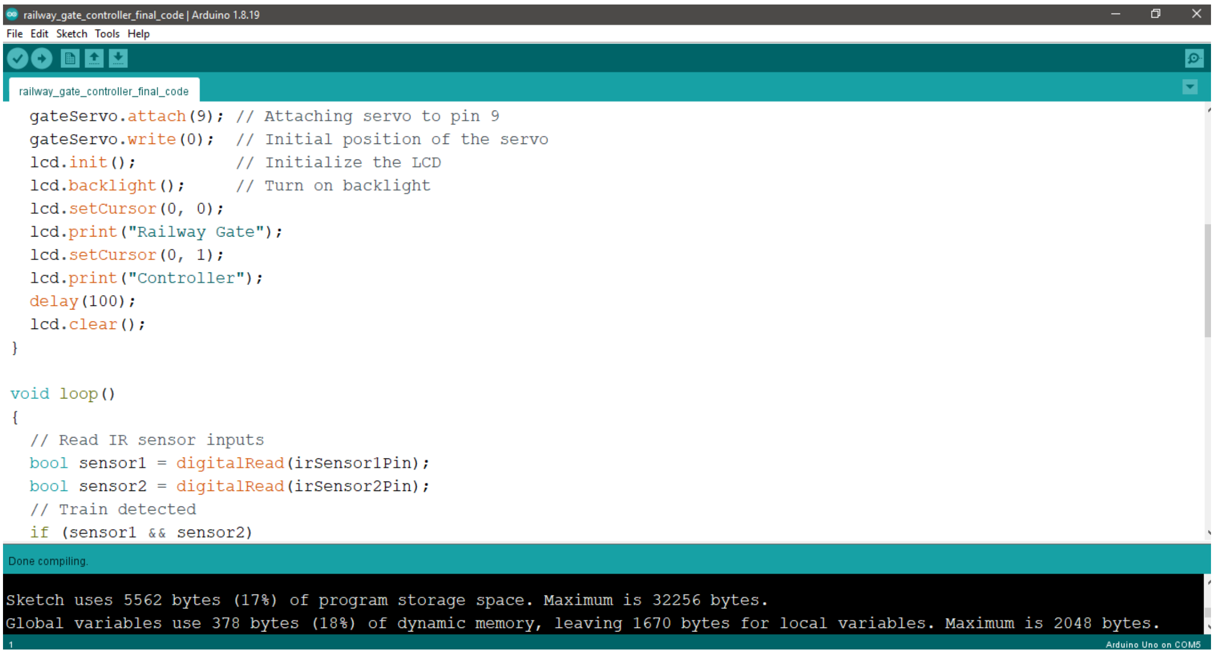

Figure 5.2 Simulation Output 2

The IR sensor serves as a reliable detection mechanism for identifying approaching trains, triggering the gate system to activate accordingly. This ensures timely closure of the gates to prevent any potential accidents or collisions at the level crossing.

Figure 5.3 Simulation Output 3

The servo motor facilitates precise and controlled movement of the railway gates, ensuring smooth operation and reliable performance. Its integration with the Arduino Uno enables automated gate movement based on inputs received from the IR sensor.

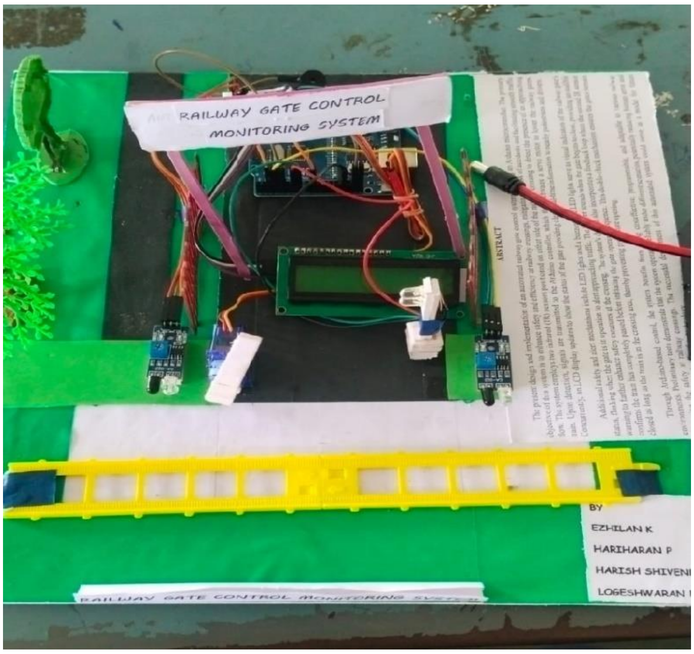

Figure 5.4 Final Model(Top view)

LED indicators provide visual cues for approaching vehicles, clearly indicating the status of the railway gates. A red LED signals a closed gate, while a green LED

Figure 5.5 Final Module(Front view)

indicates an open gate, enabling road users to make informed decisions and navigate the level crossing safely.

Additionally, the inclusion of a buzzer adds an extra layer of safety by emitting an audible alert when the gates begin to move or reach their fully closed position. This sound notification serves as a warning for nearby road users and pedestrians, enhancing awareness and minimizing the risk of accidents.

The Railway Gate Controller with Arduino Uno, LCD display, I2C converter, IR sensor, servo motor, LED, and buzzer offers a comprehensive solution for managing railway level crossings. Its combination of advanced features and seamless integration ensures enhanced safety, reliability, and efficiency in railway operations, ultimately contributing to safer transportation systems.

CHAPTER 6

CONCLUSION AND FUTURE ENHANCEMENT

6.1 CONCLUSION

The integration of Arduino Uno, LCD display, I2C converter, IR sensor, servo motor, LED, and buzzer into the Railway Gate Controller system represents a significant advancement in railway safety and efficiency. By leveraging modern technology, such as Arduino Uno microcontrollers and IR sensors, we have developed a system capable of accurately detecting approaching trains and initiating gate movements in a timely and precise manner. The addition of an LCD display, controlled by an I2C converter, provides operators and nearby individuals with real-time updates and vital information, further enhancing communication and situational awareness.

Furthermore, the incorporation of a servo motor ensures smooth and reliable gate operation, while LED visual indicators and a buzzer alert system contribute to enhanced safety for road users and pedestrians. These features provide clear signals and audible alerts about the gate's status, reducing the risk of accidents and improving overall safety at railway crossings.

In essence, the Railway Gate Controller system represents a comprehensive solution to the challenges associated with manual gate operation. By automating gate control processes and integrating advanced features, we have created a system that enhances safety, reliability, and efficiency in railway operations. Moving forward, continued innovation and advancements in railway technology will further contribute to the improvement of transportation safety and infrastructure worldwide.

6.2 FUTURE ENHANCEMENT

1. **Integration of AI and Machine Learning:** Incorporating AI and machine learning algorithms into railway gate controllers would enable predictive maintenance, allowing for the early detection of potential issues and the optimization of maintenance schedules. These algorithms could also analyse historical data to optimize gate operation schedules based on traffic patterns, reducing congestion and improving efficiency. Additionally, AI-powered fault detection capabilities could enhance system reliability by quickly identifying and addressing issues before they escalate.
2. **IoT Connectivity:** IoT-enabled railway gate controllers would enable real-time monitoring and management of gate systems from anywhere with an internet connection. This connectivity would facilitate proactive maintenance, as the system could automatically alert maintenance personnel when components require attention. Automated data collection and analysis would provide valuable insights into system performance, allowing for continuous improvement and optimization.
3. **Autonomous Operation:** Advancements in autonomous vehicle technology could lead to the development of fully autonomous railway gate controllers capable of independently detecting trains, analyzing traffic conditions, and coordinating gate movements. These systems would minimize the need for human intervention, reducing the risk of errors and improving overall efficiency. Additionally, autonomous gate controllers could communicate with other autonomous vehicles and infrastructure elements to optimize traffic flow and enhance safety.
4. **Enhanced Sensor Technology**: Advanced sensor technologies such as LiDAR or radar could improve train detection accuracy and reliability, especially in challenging environmental conditions such as fog or heavy rain. These sensors could also reduce false alarms by distinguishing between trains, vehicles, and other objects near the railway crossing. By enhancing detection capabilities, these technologies would improve overall system reliability and safety.

5. **Integration with Smart Transportation Systems:** Integrating railway gate controllers into broader smart transportation systems would enable seamless coordination with other infrastructure elements such as traffic lights, road sensors, and vehicle-to-infrastructure communication networks. This integration would optimize traffic flow, reduce congestion, and enhance safety by providing real-time information and facilitating adaptive control strategies.
6. **Energy-Efficient Design**: Energy-efficient design features such as solar panels or energy storage systems would reduce the environmental impact of railway gate controllers while improving system resilience and sustainability. By generating renewable energy or storing excess energy for later use, these technologies would reduce reliance on external power sources and minimize operational costs.
7. **Enhanced Communication and Connectivity:** Improved communication protocols and connectivity options such as 5G or satellite communication would enable faster and more reliable data transmission between gate controllers, trains, control centers, and other stakeholders. This enhanced communication infrastructure would support real-time monitoring, remote management, and seamless integration with other systems, improving overall system performance and efficiency.

REFERENCES

1. Ajay Kapu, Shivashankar, Raghava "Automation of railway gate system using IOT." *Journal of Engineering Sciences* 14.05 (2023).

2. Djordjevic, Boban, Evelin Krmac, Chen-Yu-Lin "An optimization-based digital twin for automated operation of rail level crossings." *Expert Systems with Applications* 239 (2024): 122422.

3. Malse, Noopur, Swami malode, Prit Mali "Automatic railway gate controller." *Enhancing Productivity in Hybrid Mode: The Beginning of a New Era:* 44.

4. Padovano, Antonio, Francesco Longo, Luigi Manca "Improving safety management in railway stations through a simulation-based digital twin approach." *Computers & Industrial Engineering* 187 (2024): 109839.

5. Selvakumar, R., Mani Maran. A, Janani. G "Design and development of artificial intelligence assisted railway gate controlling system using internet of things." *The Scientific Temper* 14.04 (2023): 1295-1300.

6. Sujatha. R, Hari. U, Shanthi. K "System for Automatic Gate Control on Railways", *International Journal of Advances in Engineering and Management (IJAEM)* & 2024.

7. Sun, Yi, Lai Wei, and Huanyun Dai. "Indirect Dynamic Stress Measurement of Metro Bogie Using LSTM Network in Frequency Domain." *IEEE Sensors Journal* (2024).

8. Vinit Kumar K, Vishal V, Yogesh .H "Automated Railway Level Crossing Gate Control System", *International Research Journal of Modernization in Engineering Technology and science* & 2024.

9. Wang, Yuecheng, Haixiang Lin,Dong Li "Research on a Fault Diagnosis Method for the Braking Control System of an Electric Multiple Unit Based on Deep Learning Integration." *Machines* 12.1 (2024): 70.

10. Zulwidad, Mochammad Hisam, and Indah Sulistiyowati. "Efficiency Through Automation: A Single System for Multiple Railway Guard Posts." *Buletin Ilmiah Sarjana Teknik Elektro* 5.3 (2023): 407-416.