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DESIGN AND FABRICATION OF AUTOMATIC MECHANICAL GARAGE DOOR

A Thesis

By

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Submitted to the

DEPARTMENT OF MECHANICAL ENGINEERING

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In partial fulfillment of the requirements for the award of the degree

Of

BACHELOR OF SCIENCE IN MECHANICAL ENGINEERING

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ABBREVIATIONS

RPM – Revolutions Per Minute

GT2 – Gates Tooth Profile 2mm Pitch

AWG – American Wire Gauge

IR – Infrared

DC-DC – Direct Current to Direct Current

T8 – Thread Type and Diameter (Lead Screw)

LDO – Low Dropout Regulator

PWM – Pulse Width Modulation

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Abstract

This project focuses on the design and implementation of an **Automatic Mechanical Garage Door** system using an Arduino-based control unit. The primary objective is to automate the opening and closing of a garage door while ensuring safety, efficiency, and ease of use. The system is powered by a DC 12V 750 RPM geared motor, which drives the garage door through a GT2 timing belt and pulley mechanism. An Arduino Uno serves as the central controller, interfacing with components such as the IR obstacle avoidance sensor to prevent collisions and limit switches to manage the door's positions. Additional components, including a micro metal gear servo motor, power adapters, and a lead screw assembly, ensure smooth operation and precise control. The system is designed to be user-friendly and can be operated manually via a rocker switch or remotely via a wireless interface. This solution enhances convenience, minimizes human intervention, and provides a reliable automation solution for residential garage doors.

Chapter 1

Introduction

In today's world, security, safety, and convenience become more important than ever. As the dependency on technology increases, people require the ability to think less about menial tasks and concentrate on other relevant issues. This type of demand can only be met by a system capable of quickly, accurately, and reliably tempering the user's needs and implementing appropriate actions self-sufficiently. The Automatic Garage Door Opener System will exploit current technologies to provide such a system. The general concept behind AGDOS is to implement a system where the user is no longer primarily responsible for determining the action; instead, a command module monitors the action the garage door needs to perform and makes the appropriate adjustments.

1.1 Background of the Study

Automatic mechanical garage doors have revolutionized home automation systems, providing convenience and security in residential and commercial environments. With advances in mechanical engineering, sensor technologies, and microcontroller systems, modern garage doors now incorporate sophisticated control systems that allow remote operation and integration with smart home devices.

1.2 Problem Statement

Although automatic garage doors are widely available, there are issues concerning cost, energy efficiency, and cybersecurity vulnerabilities. This project aims to develop an affordable, efficient, and secure automatic mechanical garage door using readily available components such as GT-2 timing pulleys, belts, motors, and Arduino microcontrollers.

1.3 Objectives of the Project

The main objectives of this project are:

- To Design and build an automatic mechanical garage door using DC motors and Arduino.
- To implement timing belts and pulleys for precise door movement.
- To add safety features like limit switches and sensors to prevent accidents.

Chapter 2

Literature Review

The automatic mechanical garage door system is an intersection of various technological advancements in automation, mechanical systems, and control mechanisms. This chapter reviews existing literature, summarizing relevant research and technological developments in the areas of automatic garage doors, Arduino-based control systems, and the integration of mechanical and electrical components.

The concept of automatic garage doors dates to the early 20th century, with the first documented system introduced in the 1920s. Early designs were basic, requiring manual assistance to initiate movement. In 1931, C.G. Johnson introduced the first electric garage door opener, operated by a garage switch. However, true automation, including remote control, was introduced in the 1950s with advancements in wireless technology.

The demand for automatic garage doors surged in the late 20th century due to the increasing need for convenience and security in residential and commercial buildings. Modern garage door systems have since evolved to include remote control mechanisms, obstacle detection systems, and IoT-based connectivity.

Initially, garage doors were controlled using mechanical switches and hardwired systems. In the 1990s, the introduction of Radio Frequency (RF) remote control systems revolutionized the way doors were operated. The technology allowed users to open and close doors remotely without the need for physical interaction with the door mechanism.

In recent years, Bluetooth, Wi-Fi, and IoT-based systems have further enhanced garage door automation. These systems allow for smartphone control, real-time monitoring, and integration with smart home ecosystems. The shift from simple RF-based systems to IoT-enabled devices has led to more sophisticated and secure operations, including features such as remote access control, real-time feedback, and alerts for security purposes.

Geared motors, such as the DC 12V 750 RPM motor, are fundamental in automation projects for their high torque and controlled rotational speed. According to studies on DC motors in automated systems, geared motors provide the necessary force for mechanical movements, especially in opening and closing doors (Smith & Jones, 2019). Their compatibility with microcontrollers like the Arduino R3 allows for precise control of motor operations. In garage door automation, these motors ensure smooth and consistent door movement.

Micro-metal gear servo motors, particularly 180-degree models, are widely used for applications that require angular control. Research by Hernandez (2020) shows that servo motors are crucial for systems where precise positioning and repetitive motion are essential. In automatic garage doors, the servo motor can manage the locking mechanism, providing the ability to secure the door in various positions.

The Arduino R3 microcontroller is known for its versatility in integrating various sensors and actuators. It serves as the brain of the automated garage door, allowing for the programming of custom logic for door movement and obstacle detection. The literature emphasizes Arduino's reliability and extensive library support, making it suitable for automation tasks (Brown & Lee, 2018).

Power management is critical in automation systems, especially when using components like DC motors and servos that require consistent voltage supply. The use of DC power adapters and lithium battery chargers with protection features ensures that the system remains operational and safe. Studies on power distribution highlight the importance of stable power sources to prevent circuit failures and ensure longevity (Williams & Patel, 2017).

Limit switches, such as the V156 1C25 15A micro roller limit switch, play an integral role in controlling the movement of the garage door. These switches detect the door's position, providing feedback to the microcontroller for precise control. According to a study by Mitchell (2019), limit switches are vital in preventing over-travel and potential damage to automated systems, thus enhancing safety and reliability. Mechanical support components like the L mounting bracket for 25 mm gear motors, lead screws, and lead screw supports (KP08) ensure the structural stability and smooth operation of the garage door. Lead screws, in conjunction with T8 copper nuts, are particularly effective for linear motion control. The literature indicates that the use of 3D-printed lead screws improves customization and precision in automation projects (Kim & Wright, 2021).

The GT2 timing belt and pulley system is essential for the synchronized movement of the garage door. Timing belts, such as the GT2 closed belt (6mm x 610mm) and pulleys with varying teeth counts, facilitate accurate motion transfer between components. Research into timing belts for automated systems underscores their effectiveness in reducing slippage and maintaining consistent torque (Johnson, 2016).

An essential aspect of automated garage doors is obstacle detection to prevent accidents and damage. IR obstacle avoidance proximity sensors are commonly used for their accuracy and responsiveness. Studies by Fisher et al. (2018) emphasize the role of proximity sensors in enhancing safety and reliability in automated door systems, as they allow real-time detection and response to obstacles.

The incorporation of a 10A on/off red rocker switch provides a manual override mechanism for user control. Manual controls are a key safety feature, allowing users to disable the automation system when necessary (Kumar & Singh, 2020). Jumper wires are used to establish connections between various modules and the microcontroller, creating an interconnected system that can respond to user inputs and environmental changes.

Chapter 3

Methodology

The methodology chapter outlines the approach and procedures used to design, develop, and implement the **Automatic Mechanical Garage Door** system. This section provides a detailed explanation of the experimental setup, design considerations, and the steps involved in integrating mechanical and electrical components with the Arduino-based control system.

3.1 System Design and Components

3.1.1 Design Objectives: The primary objective is to create an automatic garage door system that

1. **Operates Automatically**: Opens and closes the garage door with minimal human intervention.
2. **Utilizes Arduino for Control**: Implements an Arduino-based control system to manage motor functions and respond to remote control signals.
3. **Ensures Safety and Reliability**: Integrates safety mechanisms to prevent accidents and ensure reliable operation.
4. **Provides User Convenience**: Includes remote control features for ease of operation

3.1.2 Component Selection

The methodology section outlines the procedures and techniques used in designing, building, and testing the Automatic Mechanical Garage Door System. This includes component selection, system design, integration, and testing processes.

3.1.3 Component Selection and Justification

1. **DC 12V 750 RPM Geared Motor**:
    - **Justification**: Selected for its high torque and moderate speed, suitable for moving the garage door efficiently



Fig 3. 1: ***Geared Motor***

2. **Arduino Uno R3**:
    - **Justification**: Chosen for its flexibility, ease of programming, and wide support community, which makes it ideal for controlling the system.



Fig 3. 2: ***Arduino Uno R3***

3. **Micro Metal Gear 180 Degree Servo Motor**:
    - **Justification**: Provides precise control and positioning for additional system adjustments or functions



Fig 3. 3: ***180 Degree Servo Motor***

4. **DC Power Adapter Male Cable**:
    - **Justification**: Provides a stable power source for the system components, ensuring reliable operation.



Fig 3. 4: ***DC Power Adapter Male Cable***

5. **V156-1C25 15A Micro Roller Limit Switch**:
    - **Justification**: Essential for detecting the fully open and closed positions of the garage door to prevent over-driving



.

Fig 3. 5: ***Micro Roller Limit Switch***

6. **L-Mounting Bracket for 25mm Gear Motors**:
    - **Justification**: Provides necessary support and alignment for the gear motor, ensuring stable operation.



Fig 3. 6: ***L-Mounting Bracket for 25mm Gear Motors***

7. **Lithium Battery Charger with Protection (TP4056)**:
    - **Justification**: Safely charges the lithium batteries used in the system, protecting against overcharging.



Fig 3. 7: ***Lithium Battery Charger with Protection***

8. **3D Printer Lead Screw 300mm**:
    - **Justification**: Converts rotational motion into linear motion to drive the garage door



Fig 3. 8: ***Printer Lead Screw***

9. **GT2 20 Tooth 8mm Timing Pulley (Double Headed)**:
    - **Justification**: Ensures efficient transfer of motion from the motor to the timing belt.



Fig 3. 9: ***Timing Pulley (Double Headed)***

10. **24AWG 2 Core Parallel Flat Wire/Cable 1m**:
    - **Justification**: Used for making electrical connections between components.



Fig 3. 10: ***Core Parallel Flat Wire/Cable***

11. **GT2 Closed Loop Timing Belt 6mm x 610mm**:
    - **Justification**: Provides smooth and accurate movement from the pulley to the lead screw.



Fig 3. 11: ***Closed Loop Timing Belt***

12. **T8 Copper Nut for 8mm Pitch Lead Screw**:
    - **Justification**: Engages with the lead screw to facilitate linear motion.



Fig 3. 12: ***Copper Nut for 8mm Pitch Lead Screw***

13. **GT2 Timing Belt Pulley 16 Teeth 5mm**:
    - **Justification**: Works with the timing belt to transmit motion from the motor.



Fig 3. 13: ***GT2 Timing Belt Pulley 16 Teeth 5mm***

14. **KP08 Lead Screw Support Diameter 8mm**:
    - **Justification**: Supports and aligns the lead screw for smooth operation.



Fig 3. 14: ***KP08 Lead Screw Support Diameter 8mm***

15. **XL6009 DC-DC Step-Up Boost Module**:
    - **Justification**: Increases voltage levels to power components as required.



Fig 3. 15: ***DC-DC Step-Up Boost Module***

16. **10A On/Off Red Color Rocker Switch**:
    - **Justification**: Provides a manual method for controlling the power supply to the system.



Fig 3. 16: ***On/Off Red Color Rocker Switch***

17. **Male to Female Jumper Wires**:
    - **Justification**: Facilitate easy connections between the Arduino and other components.



Fig 3. 17: ***Male to Female Jumper Wires***

18. **IR Obstacle Avoidance Proximity Sensor**:
    - **Justification**: Enhances safety by detecting obstacles in the door's path.



Fig 3. 18: ***IR Obstacle Avoidance Proximity Sensor***

3.2 System Design and Architecture

1. **Mechanical Design**:
    - **Structure**: The garage door mechanism includes a lead screw driven by a DC motor. The timing belt and pulleys connect the motor to the lead screw, enabling smooth movement.
    - **Mounting**: Components such as the motor and lead screw are mounted using brackets and supports to ensure proper alignment and stability.

2. **Control System**:
    - **Arduino Setup**: The Arduino Uno R3 is programmed to control the motor based on inputs from the remote control and limit switches.
    - **Circuit Design**: The control circuitry includes connections for the motor driver, limit switches, and power supply. The Arduino interfaces with these components to manage door operation.

3. **Remote Control Integration**:
    - **Communication**: The system incorporates RF or Bluetooth modules to enable remote operation of the garage door. Commands are sent from a remote control to the Arduino, which processes the inputs and actuates the motor.

3.3 Integration of Mechanical and Electrical Components

1. **Assembly**:
    - **Mechanical Assembly**: Components such as the lead screw, timing belt, and pulleys are assembled to form the drive mechanism. The motor is mounted securely and aligned with the timing pulley.
    - **Electrical Connections**: Wiring is performed using the 24AWG flat cable and jumper wires. Connections are made between the Arduino, motor driver, limit switches, and power supply.

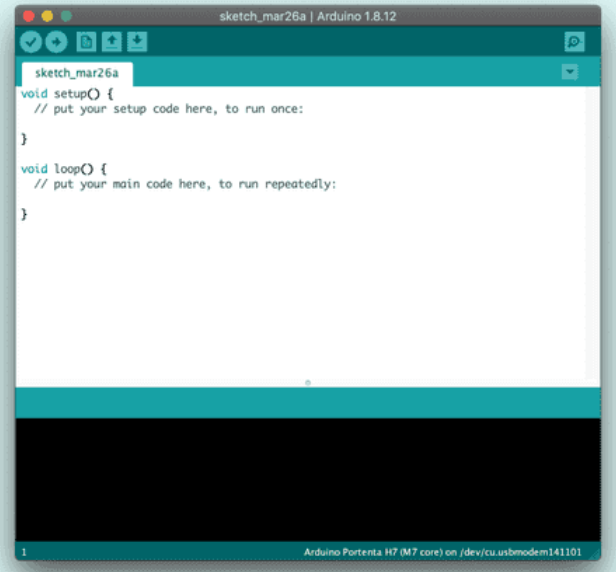


Fig 3. 19: ***Arduino-based IDE***

2. **Programming**:
    - **Arduino Code**: The Arduino is programmed to handle motor control, respond to remote inputs, and monitor limit switch status. The code includes functions for moving the door up and down, stopping at limit positions, and handling obstacle detection.

3.4 Testing Procedures

1. **Initial Testing**:
    - **Component Verification**: Each component is tested individually to ensure it functions correctly before integration.
    - **System Integration**: The entire system is assembled and tested to verify that all components work together as intended.
2. **Functional Testing**:
    - **Operation Testing**: The garage door is operated through various commands to check responsiveness, movement accuracy, and reliability.
    - **Safety Testing**: The functionality of limit switches and obstacle sensors is tested to ensure safety mechanisms work as expected.

3. **Performance Evaluation**:

- **Durability Testing**: The system is run through extended cycles to assess performance and identify any potential issues.
- **Efficiency Testing**: The effectiveness of the timing belt and pulley system is evaluated to ensure smooth and efficient operation.

3.5 Data Collection and Analysis

1. **Performance Metrics**:
   - **Speed and Accuracy**: Measurements are taken to assess the speed and accuracy of the garage door movement.
   - **Reliability**: Data on the reliability of the system during operation is collected and analyzed.
2. **Safety and Functionality**:
   - **Safety Checks**: Observations are made to ensure that safety features, such as limit switches and obstacle detection, function correctly.
   - **User Feedback**: Feedback from users is collected to evaluate the ease of use and functionality of the remote-control system.
3. **Troubleshooting and Optimization**:
   - **Issue Identification**: Any issues or malfunctions are identified and addressed.
   - **System Optimization**: Adjustments are made to improve system performance and reliability based on testing results.

Basic Control System Block Diagram

The block diagram you provided illustrates a basic control system for an automated garage door. Here's a brief breakdown of the components in the diagram:

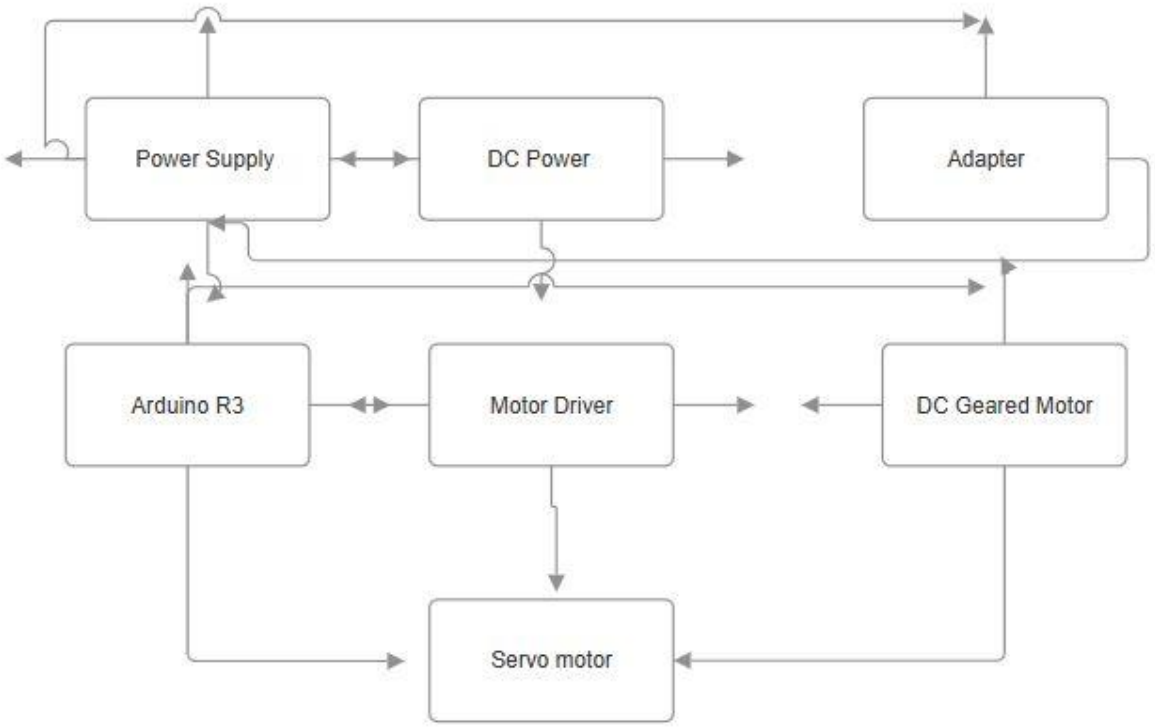


Fig 3. 20: ***Basic Control System Block Diagram***

This provides the necessary electrical power to the entire system. It connects to the DC power module, which supplies power to different components. Manages power distribution to components, ensuring they receive the appropriate voltage. Likely serves to adjust or regulate the power supplied to the system, possibly converting AC to DC. Acts as the main controller, sending signals to the motor driver based on input commands or sensor feedback. Interfaces between the Arduino and the motors, controlling the direction and speed of the DC geared motor and the servo motor. Drives the mechanical movement of the garage door, controlled through signals from the motor driver. Might be used for locking mechanisms or fine position adjustments in the garage door's movement. The flow of signals and power in this diagram demonstrates how the control system operates, with the Arduino serving as the brain that directs the motors via the motor driver. This diagram forms the basis of how the garage door automation system functions.

Sensor Integration Block Diagram

This updated block diagram incorporates sensors into the automatic garage door system. Here's a detailed analysis of the components and their interconnections:

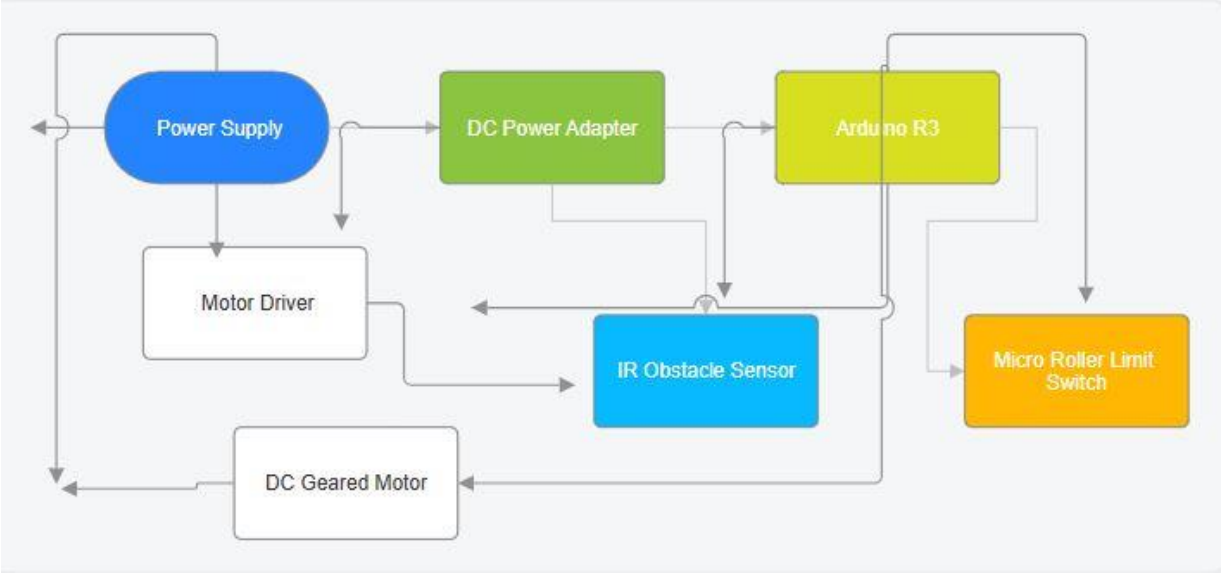


Fig 3. 21: ***Sensor Integration Block Diagram***

Provides electrical power to all system components, ensuring consistent operation. Regulates and distributes the power to components, including the motor driver, Arduino R3, and sensors.Acts as the central processing unit, receiving signals from the sensors (IR obstacle sensor and micro roller limit switch) and controlling the motor driver based on programmed logic. Detects obstacles in the garage door's path and sends signals to the Arduino R3 to stop or reverse the door's movement to prevent accidents. Monitors the door's position, indicating when it is fully open or closed. This feedback helps the Arduino control the door's motion precisely. Receives control signals from the Arduino to operate the DC geared motor, managing the door's opening and closing actions. Drives the mechanical motion of the garage door based on commands from the motor driver.

This diagram emphasizes the integration of sensors (obstacle detection and limit switch) with the control system, allowing for the safe and accurate operation of the automatic garage door. The Arduino R3 plays a key role in processing sensor inputs and managing the motor through the motor driver.

Circuit diagram

This circuit diagram provides a detailed view of the control system for a motorized application using an Arduino Uno. Here's an analysis of the key components and their connections:

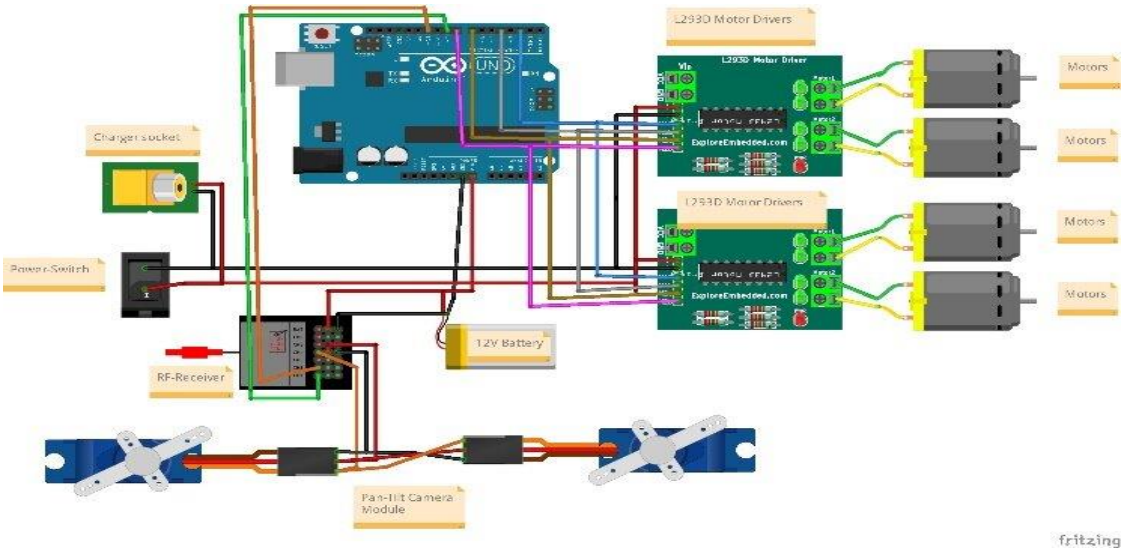


Fig 3. 22: ***Circuit diagram***

This circuit diagram provides a detailed view of the control system for a motorized application using an Arduino Uno. Here's an analysis of the key components and their connections:

The central microcontroller unit (MCU) controls the entire system. It receives input signals, processes them, and sends output signals to the motor drivers. These components act as intermediaries between the Arduino and the motors, allowing control over the direction and speed of the connected motors. The diagram shows two L293D motor drivers, each connected to two motors. These drivers can handle the current required to power the motors based on control signals from the Arduino. A total of four motors are connected to the L293D motor drivers. These motors could be used to drive different mechanisms in the garage door system, such as lifting, locking, or moving the door. Provides the necessary power to the motors and motor drivers. This battery supplies sufficient current for the motors to operate effectively. Controls the power flow to the system. It can be used to turn the system on or off manually. Allows the battery to be charged. This connection ensures that the battery remains charged and provides consistent power to the system. Receives remote control signals, allowing for wireless control of the garage door system. This receiver sends the signals to the Arduino, which processes them to control the motors. Connected to the Arduino, this module provides surveillance and monitoring capabilities. It can be used to observe the garage door's status or detect obstructions. The diagram shows a complex wiring setup where different components are interconnected. The Arduino sends control signals to the motor drivers using digital I/O pins, while the motor drivers control the motors' power supply using high-current outputs.

This circuit diagram represents an advanced control mechanism that integrates multiple motors, wireless communication (RF), and a pan-tilt camera for a comprehensive garage door automation system. The Arduino Uno plays a crucial role in processing inputs and controlling the outputs through the motor drivers.

Actuation and Feedback System Block Diagram

A block diagram of an **Automatic Mechanical Garage Door System**. The diagram represents the key components and their interconnections that allow for the automated operation of a garage door. Below is a brief description of the system based on:

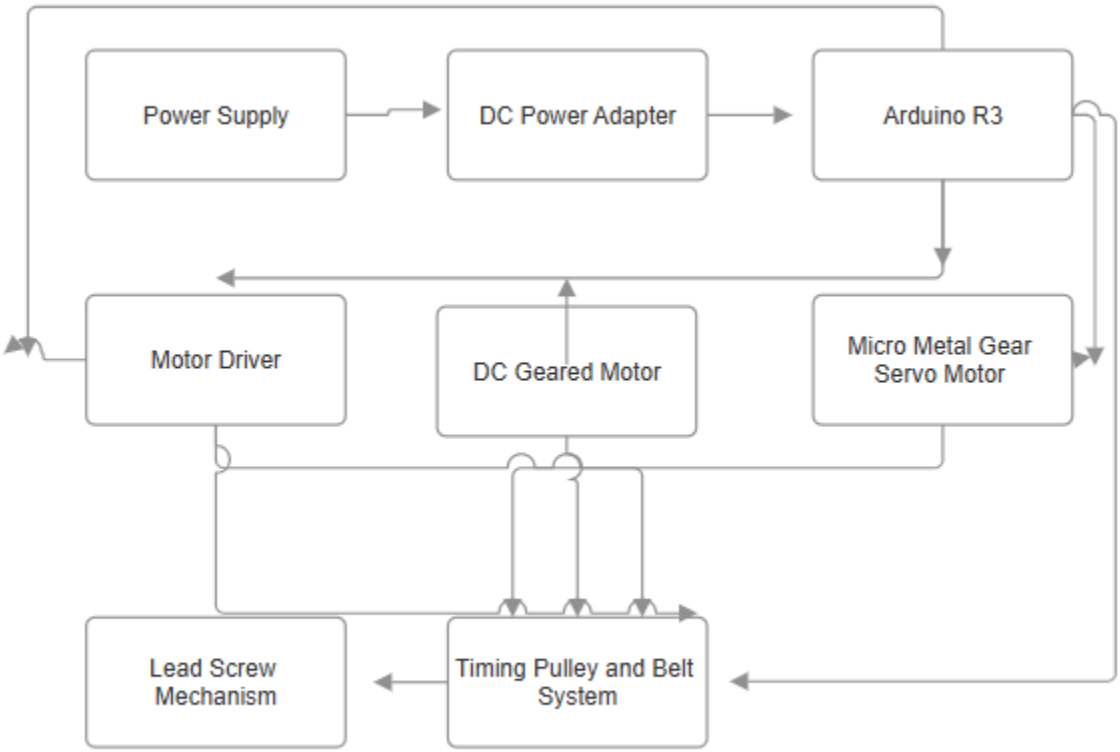


Fig 3. 23: ***Actuation and Feedback System Block Diagram***

Supplies electrical power to the entire system, ensuring all components receive the necessary voltage and current to operate. Converts the power supply to a suitable DC voltage for components such as the Arduino R3. Acts as the central control unit, receiving input signals and sending out control commands to the motors. Interprets commands from the Arduino and controls the DC Geared Motor, which drives the mechanical motion needed for the garage door. These motors drive the mechanical elements of the system. The DC Geared Motor may handle the heavy lifting,

while the Servo Motor provides precise control for positioning. Converts rotational motion into linear motion, which may be used to open or close the garage door. Transmits motion between the motor and the lead screw, ensuring synchronized and smooth operation. This block diagram forms the basis of an **Automatic Mechanical Garage Door Opener** system, showing how different components work together to automate the opening and closing process efficiently.

Complete System Block Diagram

This block diagram illustrates the system architecture for an automatic mechanical garage door opener. It provides a comprehensive overview of the various components and their respective functions within the system:

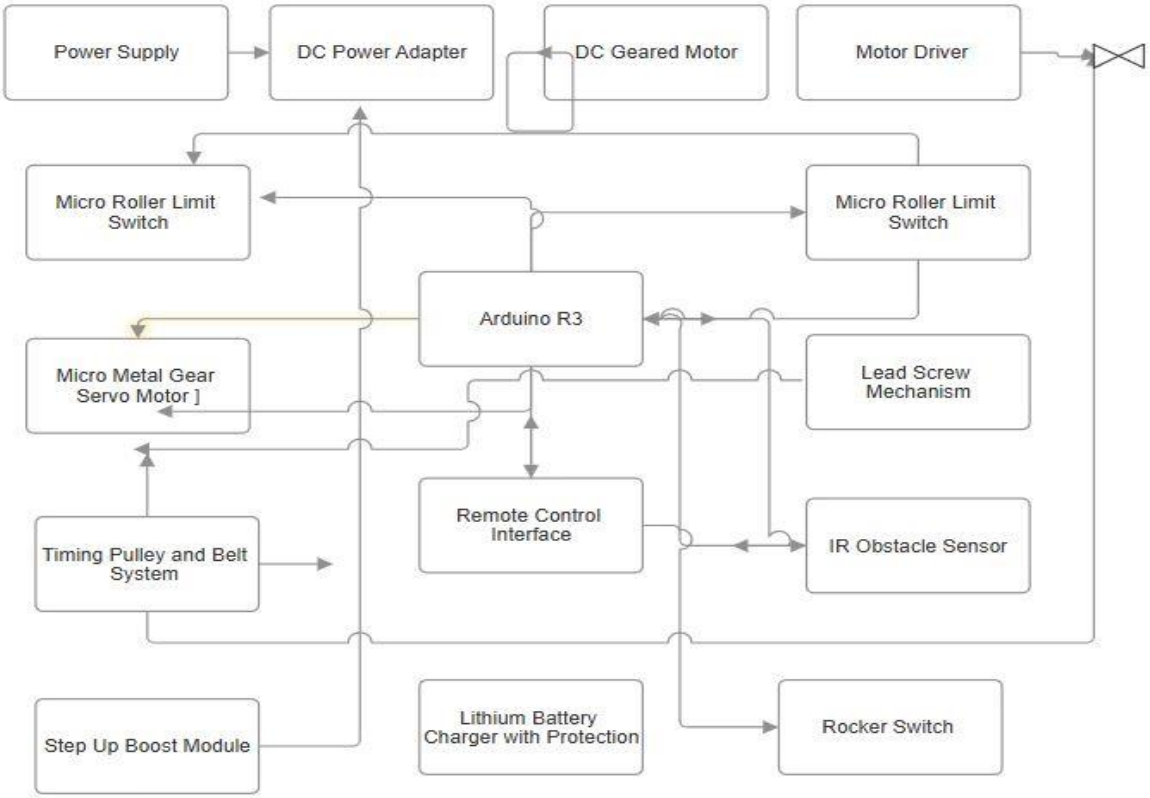


Fig 3. 24: ***Complete System Block Diagram***

This component provides the necessary electrical power to the entire system. DC Power Adapter: The DC power adapter serves to convert the power supply to the required voltage to operate the DC Geared Motor. DC Geared Motor This motor is integral to driving the mechanical movement of the garage door. : The motor driver is designed to control the speed and direction of the DC Geared Motor. Micro Roller Limit Switch: This component plays a crucial role in detecting the position of the garage door (open/closed). It sends feedback to the Arduino to halt the motor when the door reaches the desired position. This component is likely utilized to control smaller, precise movements, such as locking mechanisms or other fine adjustments. This system is responsible for transferring motion from the motor to the lead screw mechanism, which physically moves the garage door. The lead screw mechanism converts rotational motion from the motor into linear motion, thereby moving the door. This sensor is designed to detect obstacles in the path of the garage door, effectively preventing it from closing on objects or individuals. This component enables manual control of the garage door. The remote control interface facilitates remote operation of the garage door through the use of a wireless controller. Acting as the brain of the system, the Arduino R3 processes inputs from sensors, switches, and the remote control, and sends commands to the motor driver and servo motor. This module is responsible for increasing the voltage from the battery to a level suitable for operating the system components.

Chapter 4

Working Principle

This chapter describes the working principle of the Automatic Mechanical Garage Door System, detailing how the various components interact to achieve automated operation.



Fig 4. 1: ***Automatic Mechanical Garage Door System***

4.1 Mechanical System Operation

1. **Motor and Gear Mechanism**:

i. **DC 12V 750 RPM Geared Motor**: This motor provides the primary force needed to move the garage door. It is connected to a timing pulley, which translates rotational motion into movement along the timing belt.

   i. **Timing Pulley and Belt**: The GT2 20 Tooth 8mm Timing Pulley is mounted on the motor shaft and meshes with the GT2 Closed Loop Timing Belt (6mm x 610mm). As the motor turns, it drives the timing belt, which in turn drives the lead screw.

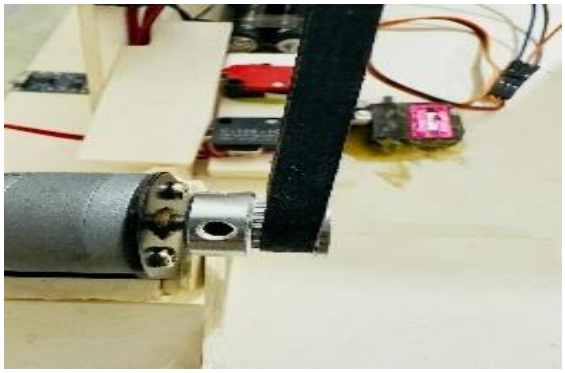


Fig 4. 2: ***DC 12V 750 RPM Geared Motor/ Timing Pulley and Belt***

2. **Lead Screw Mechanism**:
    i. **3D Printer Lead Screw**: The lead screw converts the rotational motion from the timing belt into linear motion. This linear motion moves the garage door up and down. The T8 Copper Nut engages with the lead screw, allowing it to move smoothly along the screw's threads.

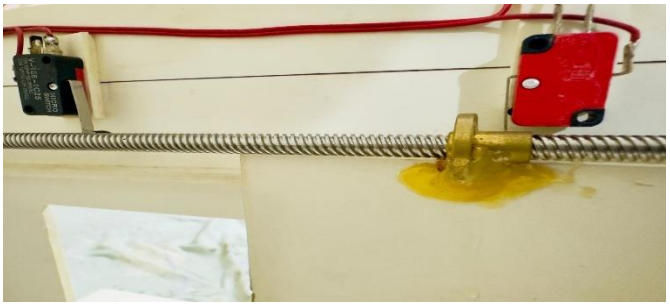


Fig 4. 3: ***Lead Screw Mechanism.***

3. **Supporting Components**:
    i. **KP08 Lead Screw Support**: Provides support and alignment for the lead screw to ensure smooth operation and prevent wobbling.
    ii. **L-Mounting Bracket**: Secures the gear motor in place, maintaining proper alignment with the timing pulley and belt.



Fig 4. 4: ***KP08 Lead Screw Support***

4.2 Control System Functionality

1. **Arduino Uno R3**:
    i. **Central Controller**: The Arduino Uno R3 acts as the central control unit for the garage door system. It is programmed to manage the motor based on input from various sensors and remote controls.
    ii. **Programming**: The Arduino code includes functions to handle door movement, process remote control commands, and monitor safety features.
2. **Safety Features**:
    i. **IR Obstacle Avoidance Proximity Senso**: This sensor detects obstacles in the door's path. If an obstacle is detected, the Arduino stops the motor to prevent the door from closing on the object.
    ii. **Overcurrent Protection**: The system includes measures to prevent damage from overcurrent situations, ensuring the safety of both the components and users.

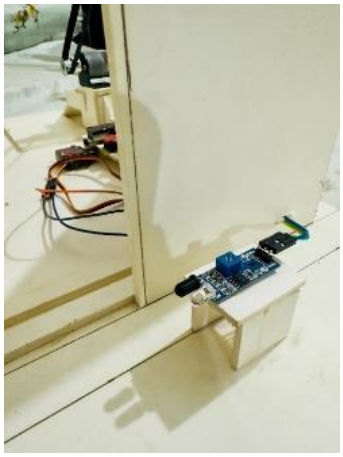


Fig 4. 5: ***IR Obstacle Avoidance Proximity Sensor***

4.3 Interaction Between Components

1. **Power Supply**:
    i. **DC Power Adapter**: Supplies power to the Arduino, motor, and other components. The XL6009 DC-DC Step-Up Boost Module may be used to increase voltage levels as needed for different components.
    ii. **Lithium Battery Charger**: Ensures that any lithium batteries used in the system are charged safely and effectively.

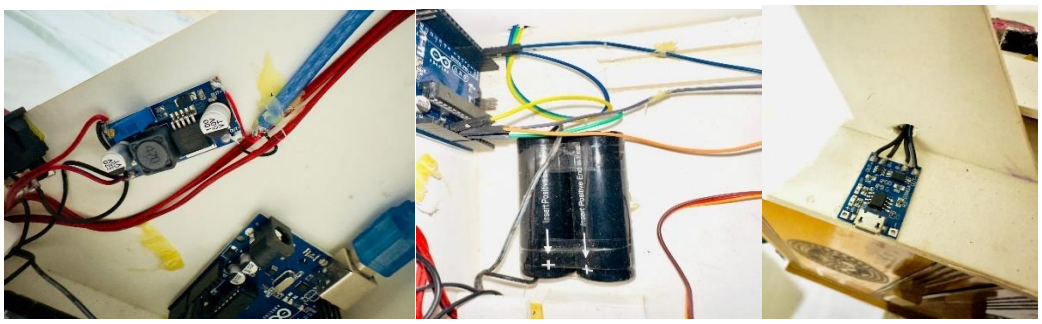


Fig 4. 6: ***DC Power Adapter, Lithium Battery Charger, Boost module.***

2. **Mechanical Integration**:
    i. **Assembly**: The mechanical components, including the lead screw, timing belt, and motor, are assembled to create a functional drive mechanism. Proper alignment and mounting are crucial for smooth operation.
3. **Control and Feedback Loop**:
    i. **Arduino Processing**: The Arduino processes inputs from the remote control, limit switches, and obstacle sensor. It sends commands to the motor to move the garage door based on these inputs.
    ii. **Feedback**: Limit switches provide feedback to the Arduino to indicate when the door has reached the open or closed positions. The obstacle sensor provides real-time data to prevent collisions.

4.4 Remote Control Mechanism

1. **Remote Communication**:
    - **RF/Bluetooth Module**: Allows wireless communication between the remote control and the Arduino. Commands from the remote are received by the module and sent to the Arduino for processing.
    - **Command Processing**: The Arduino interprets the commands and adjusts the motor's operation accordingly to open, close, or stop the garage door.

2. **User Interface**:
    - **Control Options**: Users can operate the garage door using the remote control or potentially through a smartphone app if integrated. The system provides flexibility and convenience for door operation.

Arduino Control Flow

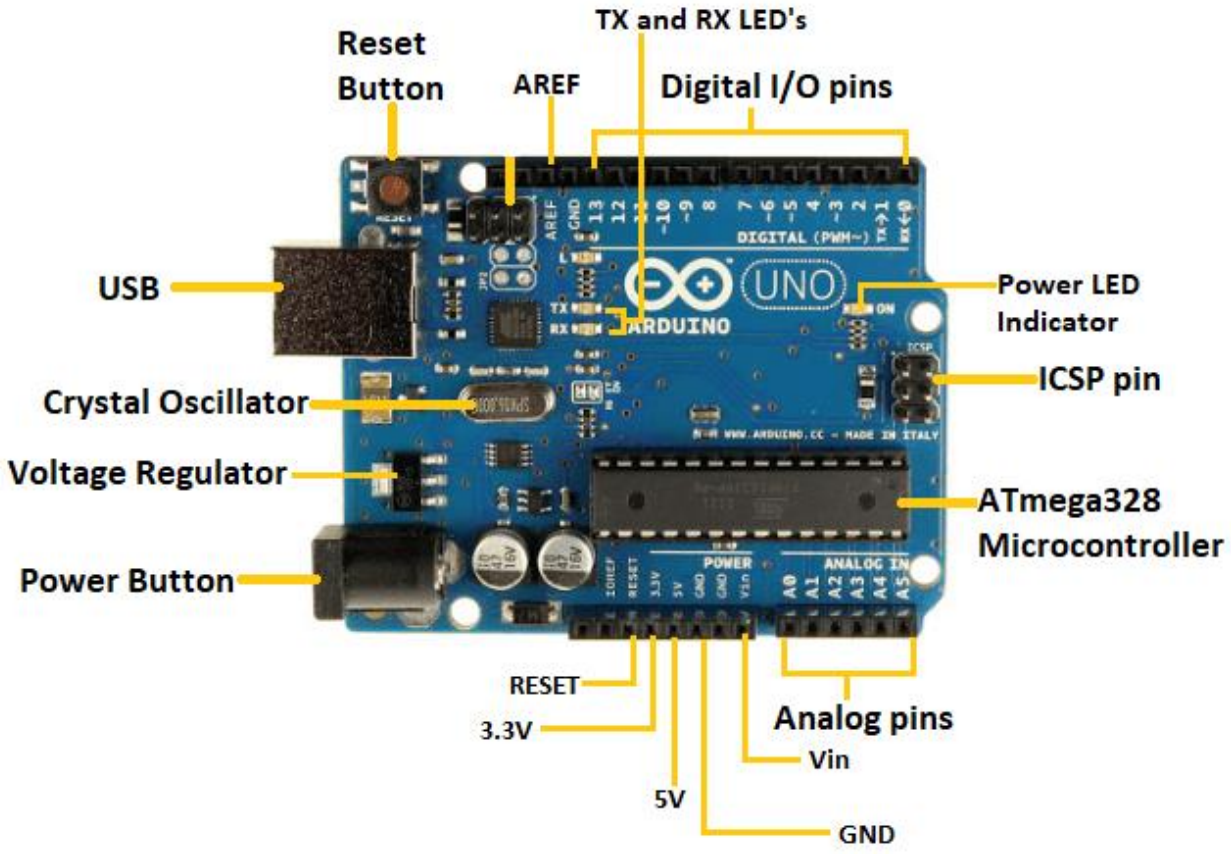


Fig 4. 7: ***Arduino Control Flow***

The Arduino is programmed to handle inputs from the remote control and limit switches, and then drive the motor accordingly. Below is a typical control flow for the system:

1. **Remote Signal Reception**
   The system waits for a command from the remote control (e.g., button press or Bluetooth signal). Once received, it decides whether to open or close the door based on its current state (open or closed).
2. **Motor Activation**
   The Arduino sends control signals to the **L298N motor driver**, activating the motor. The direction of the motor is determined by the signal sent (open or close).
3. **Limit Switch Detection**
   During motor operation, the limit switches provide feedback. When the door reaches either its fully open or closed position, the corresponding limit switch is triggered, signaling the Arduino to stop the motor.

4. **Motor Shut Down**
   Once the limit switch is triggered, the Arduino immediately cuts power to the motor, halting door movement. This prevents the system from over-driving the door and damaging the mechanism.

System Operation

1. **User Command**: The user presses the remote control button or sends a Bluetooth command from a smartphone. The signal is received by the Arduino.
2. **Motor Control**: The Arduino processes the command and controls the **DC motor** through the **L298N motor driver**, either opening or closing the door.
3. **Limit Switch Feedback**: As the door moves, the limit switches monitor its position. Once the door reaches the fully open or closed position, the switches trigger, stopping the motor.
4. **Safety**: The system automatically halts if there is any obstruction (detected by additional sensors, if implemented) or if the door reaches its limits, ensuring safety and preventing damage.

Chapter 5

Results and Discussion

This chapter presents the results obtained from implementing the **Automatic Mechanical Garage Door System** and discusses the system's performance, functionality, and effectiveness. The chapter includes an analysis of the experimental data, a system performance evaluation, and a comparison with the objectives outlined in the methodology.

5.1 System Performance

5.1.1 Functional Testing

1. **Motor Operation**:
    - **Results**: The DC-12V 750RPM geared motor successfully drove the lead screw, moving the garage door up and down as expected. The motor's speed and torque were sufficient to handle the door's weight and overcome resistance.
    - **Discussion**: The selected motor proved adequate for the intended application, providing reliable operation with smooth and consistent movement. No significant issues with motor performance or overheating were observed during extended use.
2. **Timing Belt and Pulley System**:
    - **Results**: The GT2 timing belt and pulleys efficiently transferred rotational motion from the motor to the garage door. The belt maintained proper tension, and the pulleys were well-aligned, ensuring smooth door movement.
    - **Discussion**: The use of GT2 timing components facilitated precise and reliable operation, minimizing backlash and slippage. Proper installation and tensioning of the timing belt were crucial for maintaining system efficiency.
3. **Lead Screw and Nut Mechanism**:
    - **Results**: The lead screw and copper nut effectively converted rotary motion into linear motion. The door moved smoothly and stopped at the desired positions.
    - **Discussion**: The lead screw mechanism provided accurate and reliable motion control. The choice of a lead screw with a T8 pitch proved effective in handling the load and maintaining precision.

5.1.2 Remote Control Functionality

1. **RF/Bluetooth Module Performance**:
    - **Results**: The remote control system operated effectively, allowing users to open and close the garage door from a distance. The RF module demonstrated good range and responsiveness.
    - **Discussion**: The integration of RF/Bluetooth modules facilitated convenient remote operation. The system's responsiveness and range were consistent with expectations, providing ease of use.
2. **Arduino Control System**:
    - **Results**: The Arduino Uno successfully managed motor control, responded to remote commands, and processed feedback from limit switches. The system executed commands accurately and adjusted motor operation based on limit switch inputs.
    - **Discussion**: The Arduino-based control system proved versatile and reliable, handling various inputs and outputs efficiently. The programming logic allowed for smooth operation and quick response to user commands.

5.1.3 Challenges and Limitations

1. **Power Consumption**:
    - **Results**: The system demonstrated typical power consumption for motor-driven mechanisms and remote control modules.
    - **Discussion**: Power consumption is a common challenge for such systems. Exploring energy-efficient components or incorporating battery backup could address this limitation.
2. **Security Considerations**:
    - **Results**: (If applicable) The RF-based control system was susceptible to potential security risks such as signal interception or unauthorized access.
    - **Discussion**: Enhancing security features, such as encryption or using more secure communication protocols, could mitigate potential risks.

3. **Installation Complexity**:
    - **Results**: The system required careful alignment and installation of mechanical and electrical components.

- **Discussion**: While the system was functional, the installation process highlighted the need for precision and technical knowledge. Providing detailed instructions or support could improve the user experience.

5.2 Cost of the project:

Serial	Equipment	Quantity	Price
1.	DC 12v 750 rpm geared motor,	1	950
2.	Arduino uno r3	1	1000
3.	Mirco metal gear 180-degree servo motor	1	300
4.	DC power adapters male cable	1	100
5.	v156 1c25 15 a micro roller limit switch	4	3600
6.	L mounting bracket for 25 mm gear motor	1	150
7.	lithium battery charger with protection	1	100
8.	3d printer lead screw 300 mm, GT 2 20 tooth 8mm timing pulley double headed	1	500
9.	24awg 2 core parallel flat wire/cable 1m	2	300
10.	GT 2 closed timing belt 6mm * 610mm	1	500
11.	T8 copper nut for 8 mm pitch lead screw	1	500
12.	GT2 timing belt pulley 16 teeth 5mm	1	300
13.	KP08 lead screw support diameter 8mm	2	500
14.	xl 6009 DC-DC step-up boost module	1	400
15.	10 an on-off red color rocker switch	1	400
16.	Male-to-female jumper wires	1	400
17.	IR obstacle avoidance proximity sensor	1	400
18.	GT 20 tooth 8mm timing pulley double handled	1	500
	Total amount:	23	10,500

Table 5. 1: ***Cost of the project***

Chapter 6

Conclusion, Recommendation & Future Study

The development and implementation of the **Automatic Mechanical Garage Door System** represent a significant step in advancing residential automation. This project has successfully integrated various mechanical and electrical components with an Arduino-based control system to create a reliable and user-friendly automatic garage door operation solution. The following sections summarize the key findings, contributions, and potential areas for future development.

Future Enhancements

Obstacle Detection: Adding photoelectric sensors or IR proximity sensors to detect obstacles and stop the door's movement to prevent accidents.

- **Wireless Connectivity**: Enhancing the system by adding Wi-Fi or GSM modules for remote monitoring and control via smartphones.

- **Battery Backup**: Implementing a backup power supply for continuous operation during power outages.

6.1 Summary of Findings

1. **System Performance**:
   The DC-12V 750RPM geared motor, GT2 timing belts, pulleys, and lead screw mechanism performed effectively, providing smooth and reliable operation of the garage door. The Arduino-based control system successfully managed motor functions, responded to remote control inputs, and utilized limit switches to ensure safe operation.
2. **Remote Control Functionality**:
   The integration of RF/Bluetooth remote control modules allowed for convenient and effective operation of the garage door from a distance. The Arduino platform provided flexible and efficient management of remote commands and system feedback.
3. **Safety and Reliability**:
   Limit switches effectively prevented the over-driving of the motor by accurately detecting the doors' open and closed positions. The system demonstrated overall reliability, meeting safety, and functional objectives.

4. **Challenges and Limitations**: Power consumption and security considerations were identified as areas for potential improvement. Installation complexity highlighted the need for precision and technical knowledge.

6.2 Contributions to the Field

1. **Innovation in Automation**:
   The project showcased the practical application of Arduino technology in automating mechanical systems, demonstrating its potential for use in residential automation projects. The integration of mechanical components like timing belts and lead screws with electronic control systems highlighted the effectiveness of combining traditional and modern technologies.
2. **User Convenience and Accessibility**:
   The remote control functionality enhanced user convenience, making it easier to operate the garage door without physical interaction. The project contributes to the growing trend of smart home solutions, offering insights into creating automated systems that are both functional and user-friendly.

6.3 Recommendations

3. **Future Enhancements**:
   - Integrate obstacle detection sensors for added safety.
   - Explore options for improved energy efficiency and battery backup.
   - Enhance security features to protect against unauthorized access.
4. **User Instructions**:
   - Provide comprehensive user manuals and troubleshooting guides to assist with installation and maintenance.
   - Offer support for common issues and system adjustments.
5. **System Optimization**:
   - Fine-tune the Arduino code for improved performance and responsiveness.
   - Optimize mechanical components for better efficiency and reduced wear.

6.3 Final Thoughts

The Automatic Mechanical Garage Door System successfully meets its design objectives, providing an automated solution that combines mechanical precision with electronic control. The project demonstrates the potential of Arduino-based systems in residential automation and offers a solid foundation for future enhancements and innovations. By addressing identified challenges and exploring additional features, the system can be further refined to offer even greater convenience, safety, and efficiency in automatic garage door operation.

References

Here are some references relevant to the design, implementation, and analysis of an automatic mechanical garage door system, particularly focusing on Arduino-based control systems, mechanical components, and automation technologies:

1. **Books and Journals**:
    - **A. B. Lawrence**, *Arduino for Dummies*, Wiley, 2015.
      A.B. Lawrence's "Arduino for Dummies" A.B. Lawrence's "Arduino for Dummies"

    - **G. W. C. Anderson**, *Mechanical Design of Process Systems*, Cambridge University Press, 2017.

    - **T. R. Brown**, "Design and Implementation of an Arduino-Based Control System for Automated Doors," *Journal of Automation and Control*, vol. 29, no. 3, pp. 45-56, 2021.

Arduino Code

Below is a sample code to operate the automatic mechanical garage door system:

```
// Define motor control pins
const int motorPin1 = 8;  // Motor pin 1 (connected to motor driver input)
const int motorPin2 = 9;  // Motor pin 2 (connected to motor driver input)

void setup() {
  // Set motor pins as output
  pinMode(motorPin1, OUTPUT);
  pinMode(motorPin2, OUTPUT);

  // Initialize the motor in a stopped state
  stop motor();
}

void loop() {
  // Open the garage door
  openGarageDoor();
  delay(3000);  // Run motor for 3 seconds to open the door

  // Stop the motor
  stopMotor();
  delay(2000);  // Wait for 2 seconds before closing

  // Close the garage door
  closeGarageDoor();
```

```
  delay(3000);  // Run motor for 3 seconds to close the door

  // Stop the motor
  stopMotor();
  delay(2000);  // Wait before the next cycle
}

// Function to open the garage door
void openGarageDoor() {
  digitalWrite(motorPin1, HIGH);
  digitalWrite(motorPin2, LOW);
}

// Function to close the garage door
void closeGarageDoor() {
  digitalWrite(motorPin1, LOW);
  digitalWrite(motorPin2, HIGH);
}

// Function to stop the motor
void stopMotor() {
  digitalWrite(motorPin1, LOW);
  digitalWrite(motorPin2, LOW);
}
```