Innovation & Entrepreneurship Hub for Educated Rural Youth (SURE Trust – IERY)

Design and Implementation of Microcontroller Based- Automatic Gym Weight Adjustment System

The domain of the Project

Embedded Systems and IoT

Mentor

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By

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(B.E, 4th year pursuing)

Period of the project

July 2025 to August 2025

SURE ProEd

Innovation & Entrepreneurship Hub for Educated Rural Youth (SURE Trust – IERY)

Declaration

The project titled "**Design and Implementation of Microcontroller Based- Automatic Gym Weight Adjustment System**" has been mentored by **MEHAK MAJEED**, organised by SURE Trust, from March 2025 to August 2025, for the benefit of the educated unemployed rural youth for gaining hands-on experience in working on industry relevant projects that would take them closer to the prospective employer. I declare that to the best of my knowledge the members of the team mentioned below, have worked on it successfully and enhanced their practical knowledge in the domain.

Name	**Signature**
Mr. Avinash Shahaji Shendkar	Avinash.

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Executive Summary

This project focuses on the design and implementation of a microcontroller-based automatic gym weight adjustment system. Traditional gym machines require manual placement of a pin to select weight plates, which is often inconvenient, time-consuming, and interrupts the workout flow. To address this, the proposed system automates the process using an Arduino Uno as the controller.

The system allows the user to input the desired weight through a 4×4 keypad. A stepper motor moves the locking mechanism to the appropriate plate position, and a servo motor ensures secure locking. A 16×2 LCD display provides real-time feedback on the selected weight and system status. The setup is powered by a regulated 12V supply, ensuring safe and reliable operation.

The project was successfully completed and demonstrated high reliability and accuracy in automating the weight selection process. By eliminating manual effort, the system enhances user convenience, workout continuity, and safety.

Looking ahead, the project holds significant potential for expansion. Future extensions include a repetition counter, feedback sensors for enhanced accuracy, and advanced features such as exercise target setting and smart weight adjustment based on user strength and body weight. This paves the way for an interactive, intelligent gym system with applications in both personal fitness and commercial gym setups.

Introduction

In recent years, the fitness industry has witnessed a steady rise in demand for smart and automated equipment that enhances user experience, reduces manual effort, and ensures safety during workouts. Conventional gym machines require users to manually adjust weights by inserting or removing a locking pin, which can be inconvenient, time-consuming, and prone to errors if not properly secured. Such interruptions can disrupt the exercise flow and, in some cases, even cause injuries due to improper locking.

To overcome these limitations, this project introduces a microcontroller-based automatic gym weight adjustment system. The system is designed around the Arduino Uno, which acts as the central controller for all operations. By using a keypad interface, the user can conveniently input the desired weight value. A stepper motor is employed to move the locking mechanism into the correct position, while a servo motor is responsible for securely engaging the pin with the chosen weight plate. A 16×2 LCD module provides real-time updates to the user, including the system's status and the weight selection.

The project aims to demonstrate how simple automation can improve efficiency, safety, and comfort in daily fitness routines. By integrating reliable hardware components with straightforward programming logic, the system successfully eliminates the need for manual intervention in weight adjustment. Additionally, the design is scalable, allowing for future incorporation of sensors, feedback systems, and advanced features, ultimately leading toward a next-generation interactive gym machine.

System Diagram

A] Mechanical Representation of Automatic Gym Weight Adjustment System

Fig 1.1- Front View

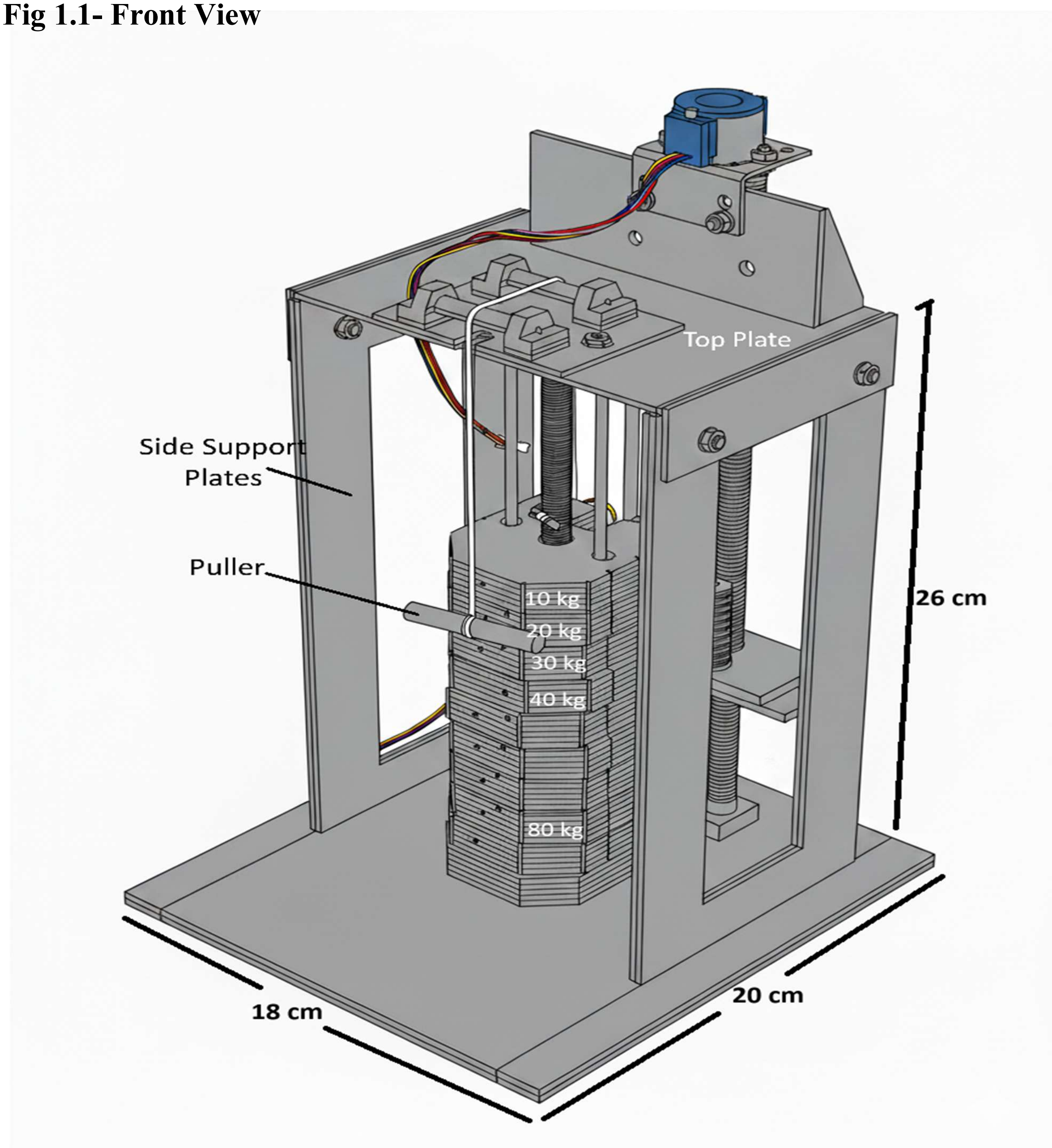


Fig 1.2- Back View

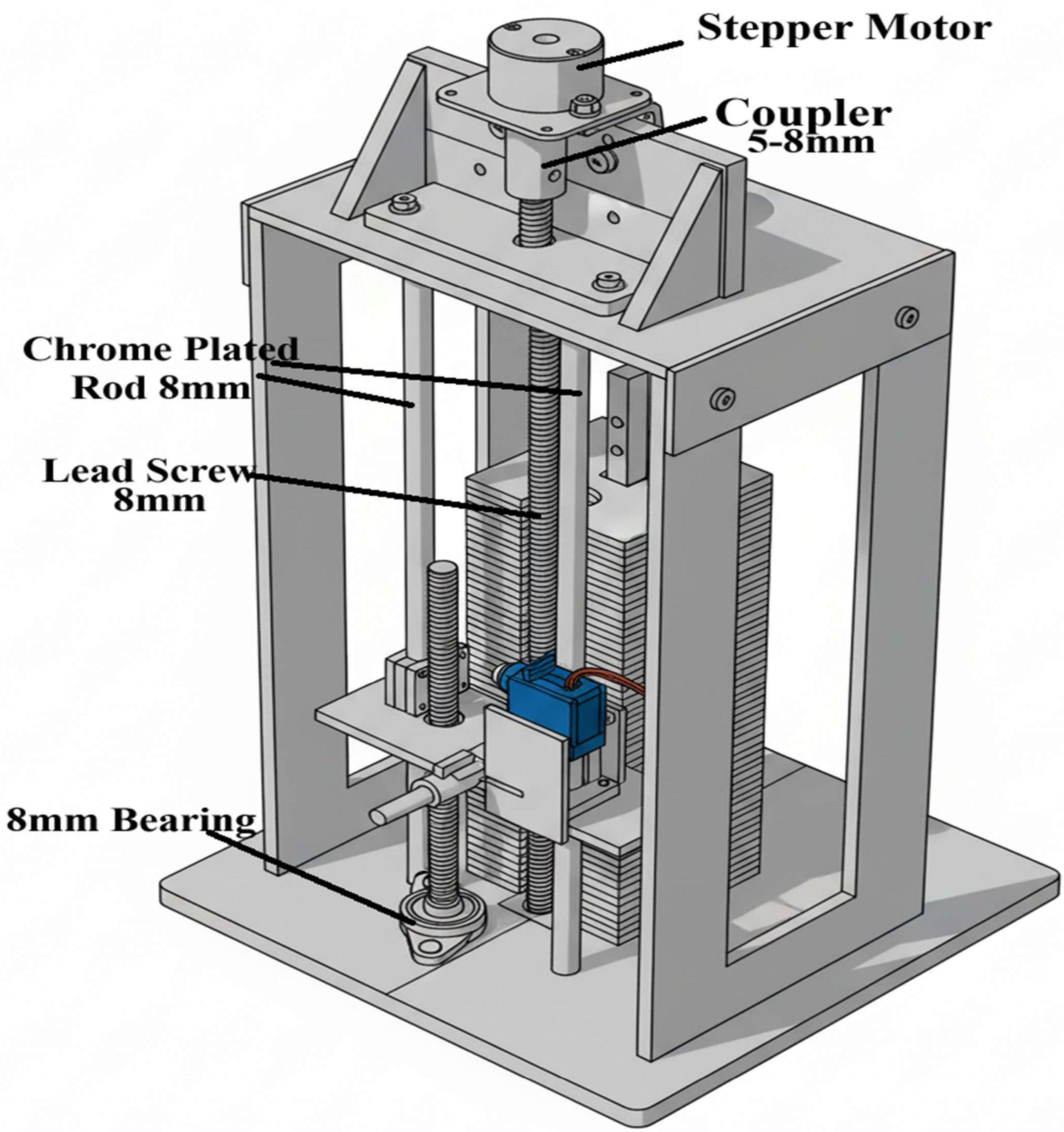
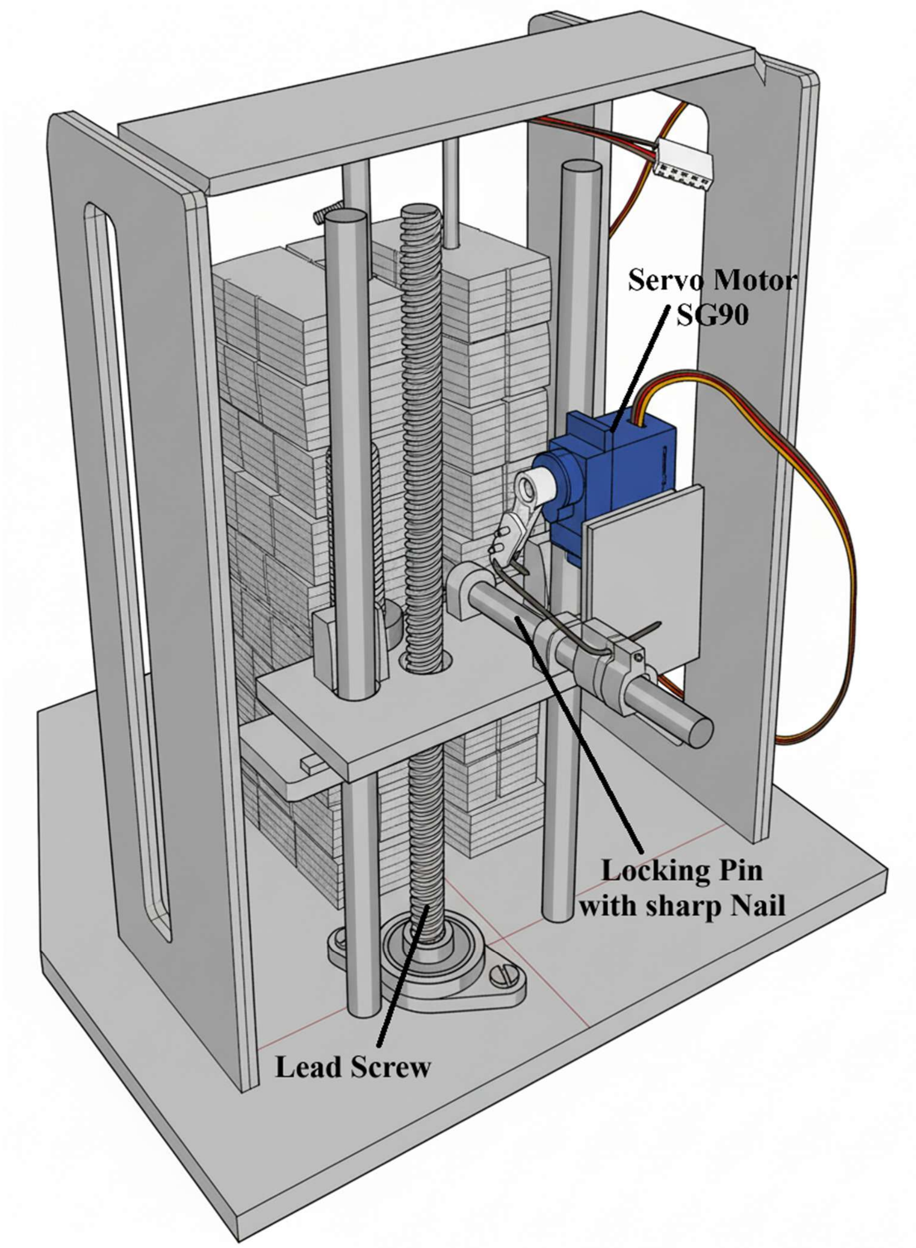


Fig 1.3- Locking Mechanism



B] Electronic Representation of Automatic Gym Weight Adjustment System

Fig 2.1- Block Diagram

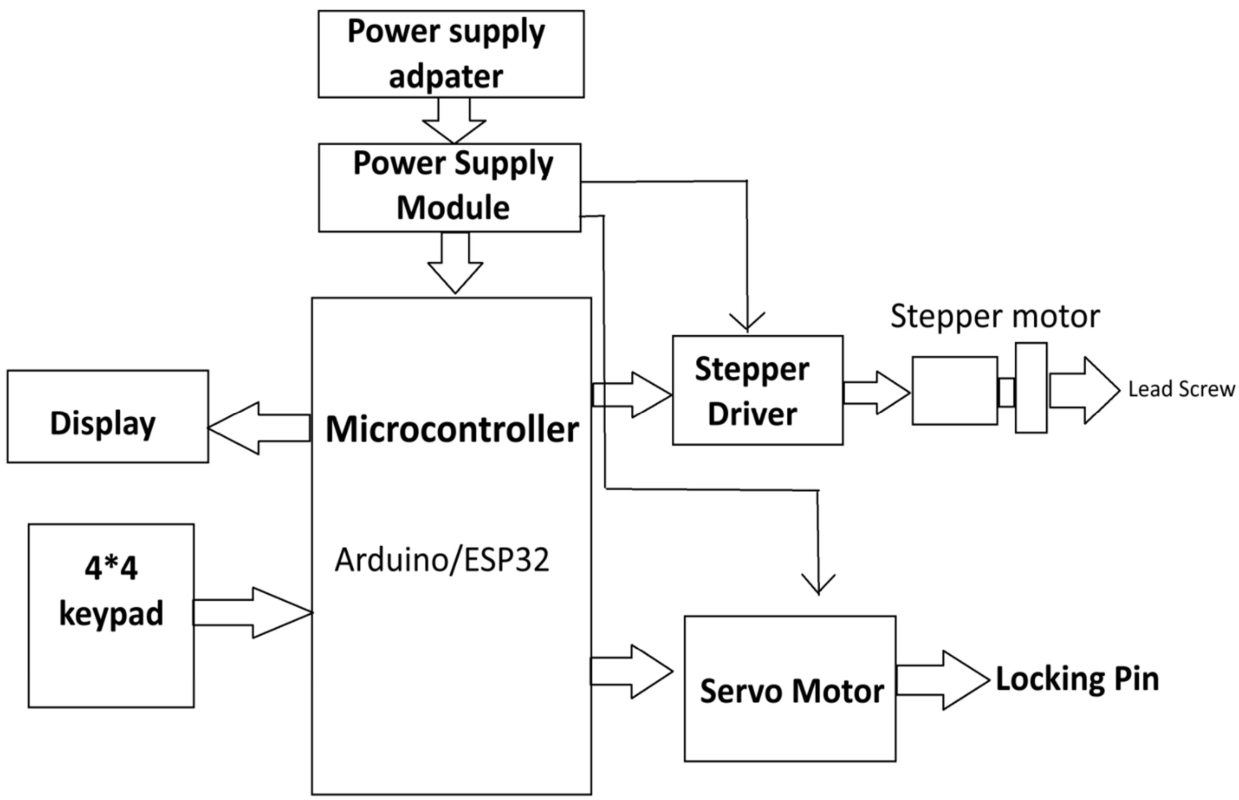
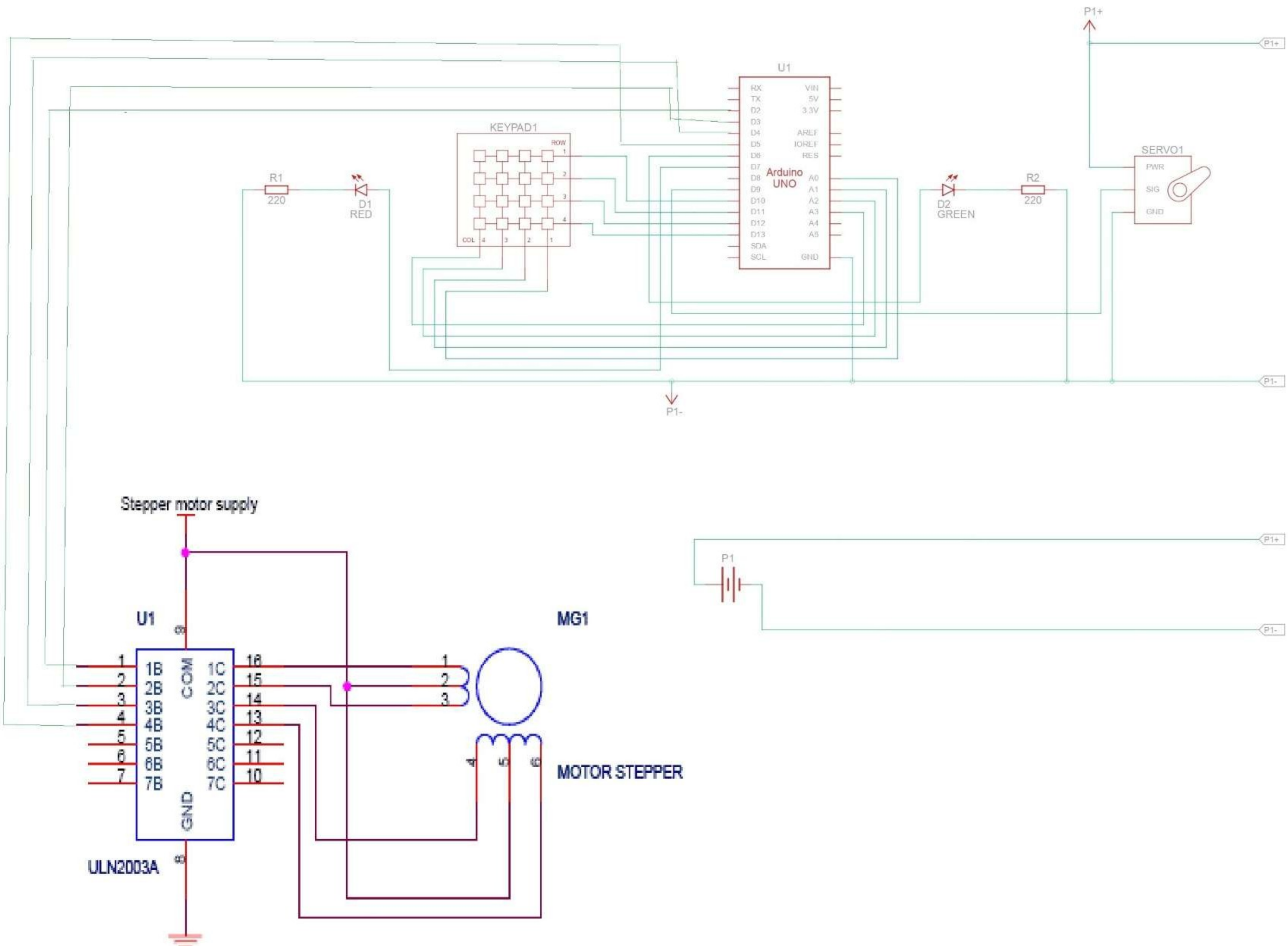


Fig 2.2- Circuit Diagram (Schematic)



Project Objectives

1. **Automation of Weight Selection**
   - To design and implement a system that eliminates the need for manual pin adjustment in gym equipment by automating the weight locking process.
2. **User-Friendly Input System**
   - To provide a simple interface using a 4×4 keypad for users to enter their desired weight quickly and conveniently.
3. **Accurate and Secure Locking Mechanism**
   - To ensure the selected weight plate is reliably locked using a servo motor for safety and stability during workouts.
4. **Real-Time Feedback**
   - To integrate a 16×2 LCD display to show the selected weight and system status, enhancing usability and confidence.
5. **Reliable Motor Control**
   - To utilize a **stepper motor** for precise positioning of the locking mechanism, ensuring correct alignment with the weight plate holes.
6. **Power Efficiency and Safety**
   - To design the system with regulated power supply and basic safety considerations for stable operation in a gym environment.
7. **Foundation for Smart Gym Systems**
   - To develop a scalable prototype that can be further expanded with advanced features such as repetition counting, feedback sensors, and intelligent weight adjustment, contributing to the future of interactive fitness equipment.

Methodology and Results

The project followed a systematic approach, combining hardware design, microcontroller programming, and prototype testing. The methodology can be divided into the following stages:

1. User Input

- A 4×4 keypad was interfaced with the Arduino Uno to allow users to enter the desired weight.
- The microcontroller processed the input and calculated the corresponding position of the weight plate.

2. Motor Control

- A stepper motor was used to move the locking mechanism vertically along a lead screw arrangement.
- The stepper provided precise control over movement, ensuring that the locking mechanism aligned accurately with the selected weight plate.

3. Weight Locking Mechanism

- Once the desired plate position was reached, a servo motor rotated its arm to insert a pin into the plate's slot.
- This ensured that the weight was firmly locked, preventing slippage during exercise.

4. Reset and Change

- To change the weight, the system disengaged the pin via the servo, repositioned the mechanism using the stepper motor, and then locked the new plate.
- This made weight switching seamless and fast compared to traditional manual pin adjustment.

5. Display & Feedback

- A 16×2 LCD was programmed to display the selected weight and system status in real-time.
- This provided users with clear confirmation of their input and the machine's response.

6. Power Supply

- The system was powered by a 12V adapter, with voltage regulation for logic-level components (5V for Arduino, servo, and LCD).
- This ensured stable operation of motors and control electronics.

Results

- The prototype was successfully implemented and demonstrated reliable operation in selecting and locking weights.
- The system responded accurately to keypad inputs, with the stepper motor consistently moving to the correct plate position.
- The servo motor locked and unlocked smoothly, ensuring secure placement of the pin.
- The LCD display provided clear and real-time updates, enhancing user confidence.
- The system proved to be highly reliable, accurate, and user-friendly, with no major errors or failures observed during testing.

Overall, the project achieved its primary goal of automating gym weight adjustment and demonstrated strong potential for further enhancement in future iterations.

Test Reports

Test Setup:

- Controller: Arduino Uno
- Motors: 28BYJ-48 Stepper (5V), Servo-based linear locking
- Weights: 10–80 kg (increments of 10 kg)
- Power: 12V adapter with 5V regulation
- Motor Control: Stepper active only during movement; sleep mode after locking

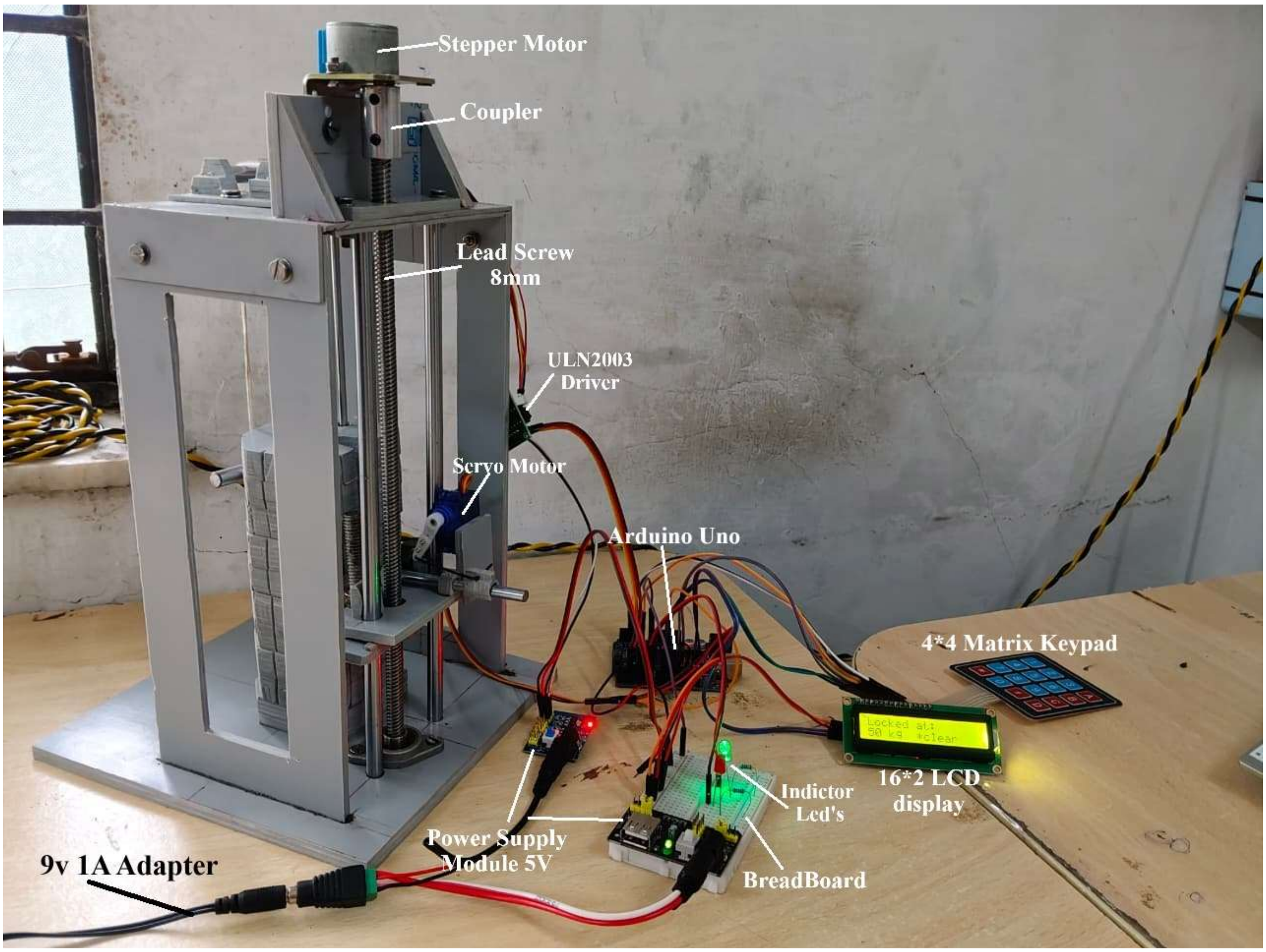
Results:

Weight (kg)	Transition (From → To)	Time (sec)	Stepper Current (mA)	Locking Status
10	Initial → 10	3.8	~450	Locked Securely
20	10 → 20	3.7	~480	Locked Securely
40	30 → 40	3.6	~470	Locked Securely
60	50 → 60	3.9	~500	Locked Securely
80	70 → 80	4.0	~450	Locked Securely

Observations & Analysis

- Transition time between consecutive weights remained consistent (3.5–4 seconds) due to servo unlocking + stepper displacement + servo locking sequence.
- Since no load acts directly on the stepper motor during displacement, standard current consumption values were observed (≈450 mA at 5V, as per test).
- The sleep mode design ensured zero idle current draw, preventing overheating of motor driver and saving energy.
- Locking was 100% reliable across all tested weights.
- System performance demonstrates stability, repeatability, and energy efficiency.

- **Picture**


Stepper Motor
Coupler
Lead Screw 8mm
ULN2003 Driver
Servo Motor
Arduino Uno
4*4 Matrix Keypad
16*2 LCD display
Indictor Led's
BreadBoard
Power Supply Module 5V
9v 1A Adapter

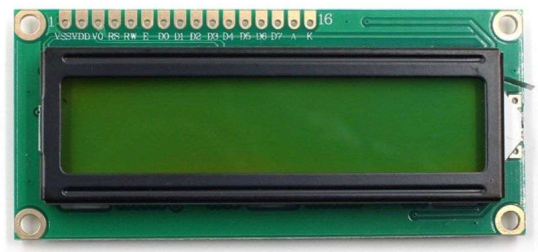
- ## Components Used

1. **Arduino Uno**

2. **28byj48 Stepper Motor 5V**

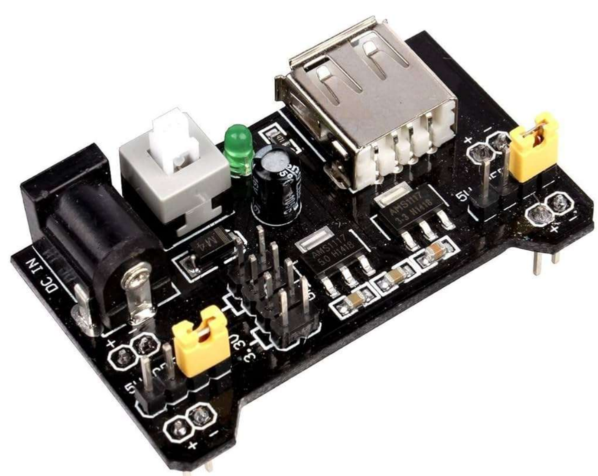
3. **Servo SG90**

4. 16*2 LCD display



5. 4*4 Matrix Keypad

6. Power Supply Module



Social / Industry Relevance of Project

The fitness industry is rapidly evolving with the integration of smart technologies aimed at improving user experience, safety, and personalization. This project directly contributes to this trend by offering an innovative solution to a common problem faced in gyms: the manual adjustment of weight plates.

Social Relevance

- **Convenience and Accessibility**: Automating the weight adjustment process makes gym equipment more user-friendly, especially for beginners, elderly individuals, or people with physical limitations who may struggle with manual pin placement.
- **Safety Enhancement**: Improperly placed pins are a frequent cause of accidents in gyms. The automated locking system ensures accurate placement every time, reducing the risk of injury.
- **Encouraging Fitness Habits**: By minimizing interruptions during workouts, the system allows for a smoother exercise flow, potentially encouraging more consistent fitness routines.

Industry Relevance

- Smart Gym Equipment: With the growing demand for IoT-enabled and intelligent gym machines, this project demonstrates a practical step toward next-generation fitness equipment.
- Commercial Applications: Gyms, fitness centers, and rehabilitation facilities can benefit from automated systems that save time and increase safety for their clients.
- Scalability: The system can be enhanced with sensors, wireless control, and AI-driven personalization, aligning with industry trends in smart fitness and health monitoring.
- Competitive Edge: Manufacturers adopting such automation can differentiate their equipment in the market by offering greater safety, interactivity, and user satisfaction.

In essence, the project addresses both social needs—by promoting safer and more inclusive fitness—and industry needs, by paving the way for the commercial adoption of smart gym technologies.

Learning and Reflection

Working on this project provided valuable hands-on experience in combining electronics, programming, and mechanical systems to solve a real-world problem. Several important technical and personal learnings were gained during the process:

Technical Learnings

- Microcontroller Programming: Learned to program the Arduino Uno for handling multiple peripherals such as a keypad, LCD, stepper motor, and servo motor simultaneously.
- Motor Control: Gained practical understanding of stepper motor control for precise positioning and servo motor operation for secure locking.
- System Integration: Developed skills in integrating input devices, actuators, and display modules into a unified, reliable system.
- Power Management: Understood the importance of regulated power supply for stable operation of motors and microcontroller components.

Problem-Solving and Design Approach

- Learned to translate user requirements (easy, safe, and fast weight adjustment) into a working hardware solution.
- Dealt with challenges such as aligning the locking mechanism accurately and ensuring that the motors worked smoothly without missteps.
- Developed troubleshooting skills for debugging both hardware and software issues.

Personal & Professional Growth

- Improved project planning and execution skills, moving from idea to a working prototype.
- Enhanced critical thinking and creativity in designing an innovative fitness-related solution.
- Experienced the satisfaction of building a project that has both practical relevance and future industrial potential.

Overall, the project was not only a technical exercise but also a learning journey that strengthened both engineering knowledge and problem-solving abilities.

Main Code and File Structure

File and Folder Structure (Arduino IDE)

In Arduino IDE, each project is saved as a sketch folder, and the main .ino file must have the same name as the folder. The following structure was used in this project:

```
AutoGymWeightSystem/          ← Main project folder
│
├── AutoGymWeightSystem.ino   ← Main Arduino sketch (main code)
│
├── /libraries                ← Required external libraries
│   ├── LiquidCrystal_I2C/    ← For LCD display
│   ├── Keypad/               ←For keypad input
│   ├── Servo/                ← For servo mechanism
│   └── EEPROM/               ← For non-volatile memory
│
└── README.txt                ← Description of pin connections & setup (body)
```

Main Code

(a) Library Imports and Configuration

```
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
#include <Keypad.h>
#include <Servo.h>
#include <EEPROM.h>

// Pin configuration
#define IN1 2
#define IN2 4
#define IN3 3
#define IN4 5
#define SERVO_PIN 9
#define GREEN_LED 6
#define RED_LED
```

(b) Stepper & Servo Control

// Stepper motor sequence (28BYJ-48)

```
const int stepSequence[4][4] = {
  {1,0,1,0},
  {0,1,1,0},
  {0,1,0,1},
  {1,0,0,1}
};

// Move stepper motor steps
```

```
void moveStepperSteps(long steps) {
  int dir = (steps > 0) ? 1 : -1;
  for (long i = 0; i < abs(steps); i++) {
    stepIndex += dir;
    if (stepIndex > 3) stepIndex = 0;
    if (stepIndex < 0) stepIndex = 3;

setStepperPins(stepSequence[stepIndex]);
delay(STEP_DELAY_MS);
  }
  releaseStepper(); // enter sleep mode
}
// Servo-based linear lock
void doUnlock() { lockServo.write(108); }
// unlock
void doLock()   { lockServo.write(6);   }
```

(c) Main Loop (Weight Selection)

```
void loop() {
  char key = keypad.getKey();
  if (key == '#') {   // confirm input
    int val = inputBuffer.toInt();
    if (val % 10 == 0 && val >= 10 && val
<= 80) {
      int targetIdx = (val - 10) / 10;

      // Unlock, move, lock
      doUnlock();
      delay(500);
      long                steps              =
calculateStepsBetweenIndices(currentInde
x, targetIdx);
      moveStepperSteps(steps);
      doLock();

      // Update state & display
      currentIndex = targetIdx;
      saveIndexToEEPROM(currentIndex);
      lcd.print("Locked at " + String(val) +
"kg");
    }
  }
}
```

Conclusion and Future Scope

Future Scope

While the current system successfully automates the locking mechanism of gym weights, there are several opportunities to enhance its functionality and usability in future developments:

1. Repetition Counter – Integration of sensors to count the number of repetitions automatically, helping users track workout progress.
2. Feedback System – Incorporation of limit switches and IR sensors to provide precise feedback for accurate positioning and locking of the mechanism.
3. Exercise Target Setting – Allowing users to set exercise goals such as the number of sets, repetitions, or duration, making workouts more interactive.
4. Smart Weight Adjustment – Advanced features where the system can recommend or adjust weight automatically based on a user's body weight, strength, and performance.
5. Interactive and Connected System – Future versions could integrate with mobile applications or IoT platforms, enabling data storage, workout tracking, and personalized fitness guidance.

Conclusion

The project "Design and Implementation of a Microcontroller-Based Automatic Gym Weight Adjustment System" successfully demonstrated the potential of automation in fitness equipment. By using an Arduino Uno, keypad, stepper motor, servo motor, and LCD display, the system was able to reliably select and lock the desired weight plate without manual intervention.

The results proved the system to be accurate, reliable, and user-friendly, thereby reducing workout interruptions and enhancing user safety. The project not only achieves its primary objectives but also establishes a strong foundation for developing next-generation smart gym machines. With future advancements such as repetition tracking, sensor feedback, and intelligent weight adjustment, the system can evolve into a fully interactive fitness solution with applications in both personal and commercial gym environments.