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Design and Development of An Elevator System with Bluetooth Using the ATmega 32 Microcontroller with Loadcell

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***Abstract* – Modern elevator systems demand improved ride comfort, safety, and intelligent control. This paper presents the design and implementation of a Bluetooth-enabled intelligent elevator system integrated with a load cell and a PID control algorithm. The proposed system allows wireless floor selection through a mobile application while ensuring smooth and stable elevator motion using closed-loop PID control. A load cell continuously monitors the cabin load to prevent overload conditions and dynamically adjust motor control parameters. The PID algorithm regulates motor speed and position to minimize overshoot, oscillations, and settling time during vertical movement. Experimental results obtained from a prototype model demonstrate enhanced speed regulation, improved safety, and reliable wireless operation. The proposed system offers a low-cost and efficient solution for smart elevator applications in low-rise buildings and educational environments.**

Keywords – elevator system, Bluetooth control, Load cell, PID controller, Embedded systems, Motor control.

1. INTRODUCTION

Elevators are an essential component of modern infrastructure, providing vertical transportation in residential and commercial buildings. Conventional elevator systems typically employ relay-based or PLC-based control mechanisms with wired push-button interfaces[1]. These systems often lack flexibility, intelligent feedback, and advanced motion control, leading to jerky movement and higher maintenance costs with the advancement of embedded systems, wireless communication, and control algorithms, intelligent elevator systems can be developed to enhance user convenience and ride comfort. Bluetooth technology enables short-range, low-power wireless communication between a mobile device and the elevator controller[2]. Meanwhile, the integration of load cells enhances passenger safety by preventing overload conditions. This paper proposes a Bluetooth-enabled intelligent elevator system that uses a PID control algorithm to achieve smooth and precise motor control. The inclusion of a loadcell provides real-time weight monitoring, enabling adaptive control and safety enforcement.

2. OVERVIEW OF EVLEVATOR SYSTEM

The proposed system presents the design and development of a Bluetooth-enabled elevator controlled by an ATmega32 microcontroller with integrated load sensing and PID-based motor control[6}. The system enables wireless floor selection via a Bluetooth interface, allowing real-time command transmission from a mobile device to the controller.

The ATmega32 serves as the central processing unit, handling elevator scheduling, direction control, and safety monitoring[7]. A load cell interfaced through a signal conditioning module provides continuous measurement of cabin load, and the controller inhibits elevator operation when the load exceeds predefined safety limits.

Elevator motion is driven by a DC motor regulated using a software-implemented Proportional–Integral–Derivative (PID) controller. The PID algorithm dynamically adjusts the motor drive signal to minimize speed and position error, ensuring smooth acceleration, controlled deceleration, reduced overshoot, and accurate floor leveling.

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3. SYSTEM ARCHITECTURE

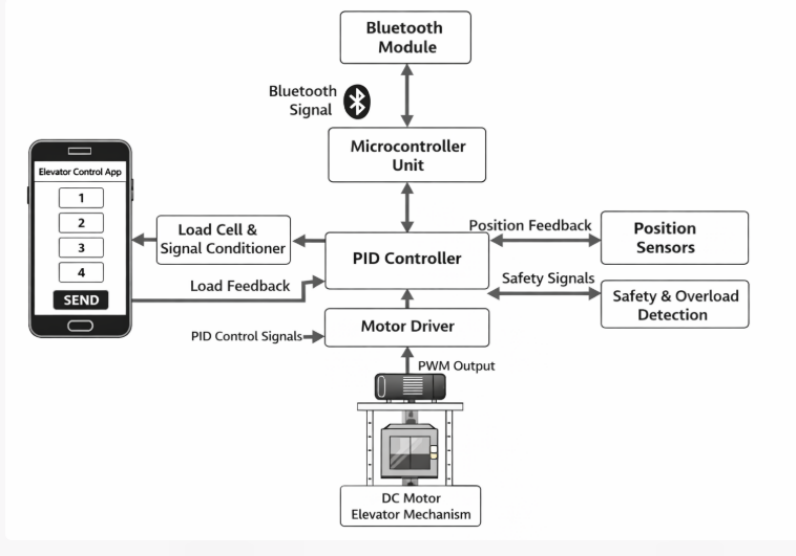

Fig. 1 :Block diagram Bluetooth controlled elevator using Arduino

The figure 1 shows the block diagram of Bluetooth-enabled intelligent elevator system is composed of a mobile user interface, a wireless communication module, an embedded control unit, and feedback-based actuation components. A smartphone application allows users to select the desired floor, and the command is transmitted to the elevator controller via a Bluetooth module. The microcontroller acts as the central processing unit, interpreting user commands and executing control logic. A load cell mounted beneath the elevator cabin continuously measures the applied load and sends real-time feedback through a signal conditioning module. Position sensors installed at each floor provide precise location feedback. A PID control algorithm processes position and load feedback to generate PWM control signals. These signals regulate the motor driver to control the elevator motor smoothly. Safety logic continuously monitors overload and abnormal conditions. The integrated architecture ensures reliable wireless operation, precise motion control, and enhanced passenger safety.

4.CIRCUIT DIAGRAM

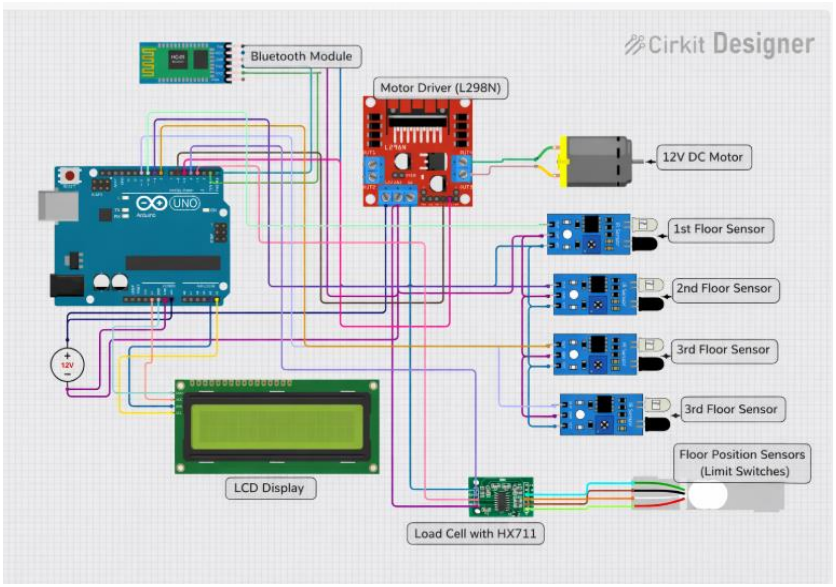

Fig 2: Circuit diagram of Bluetooth-enabled elevator system

The figure 2 illustrates the complete wiring diagram of a Bluetooth-enabled intelligent elevator control system. An Arduino UNO acts as the main controller, interfacing with the HC-05 Bluetooth module for wireless floor selection. The L298N motor driver controls the DC motor responsible for elevator movement. Multiple floor position sensors detect the cabin location at each floor to

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ensure accurate stopping. A load cell with HX711 module measures cabin load to prevent overloading. The LCD display provides real-time status such as floor number and system message.

5.PID CONTROLLER

In the proposed Bluetooth-enabled elevator system, a Proportional–Integral–Derivative (PID) controller is employed to regulate the speed and position of the elevator motor under varying load conditions. Floor commands received via Bluetooth are processed by the microcontroller to generate a reference position or speed. The load cell continuously measures the cabin load, which influences the system dynamics and is accounted for in the control process.

The PID controller minimizes the error between the desired elevator position and the actual position obtained from sensors. The proportional term provides immediate corrective action, the integral term eliminates steady-state error caused by load variations, and the derivative term improves system stability by reducing overshoot during acceleration and deceleration.

The standard continuous time PID controller equation for motor control is

$$C_o(t) = K_P e(t) + K_i \int_0^t e(\tau)d\tau + K_d \frac{de(t)}{dt} \qquad (1)$$

The equation (1) represents PID controller representation. Where $C_o(t)$ is the controller output at time t, e(t) is the error (reference point minus feedback speed) and K_P, K_i, K_d are proportional, integral and derivative gains respectively. The discrete-time equivalent sums the proportional, integral and derivative terms based on the error at each sampling instant.

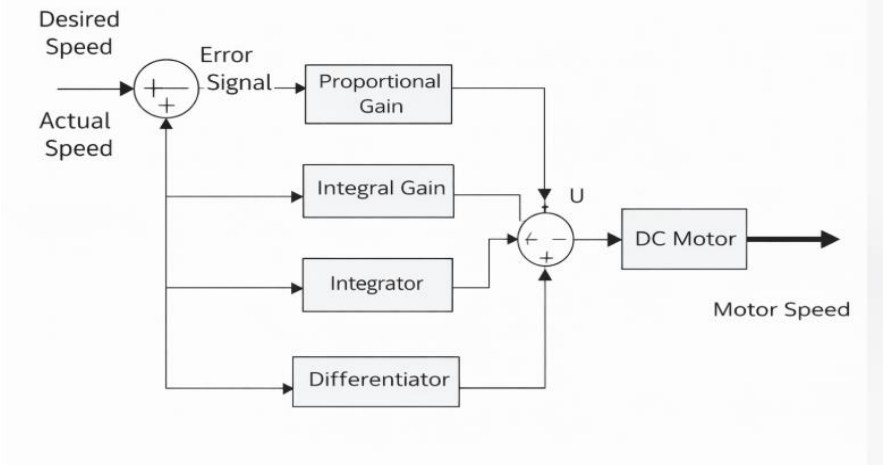

Fig. 3 : Block Diagram of PID Controller for DC motor.

Figure 3 shows the brief explanation of the elevator control. The PID controller minimizes the error between the desired elevator position and the actual position obtained from sensors. The proportional term provides immediate corrective action, the integral term eliminates steady-state error caused by load variations, and the derivative term improves system stability by reducing overshoot during acceleration and deceleration.

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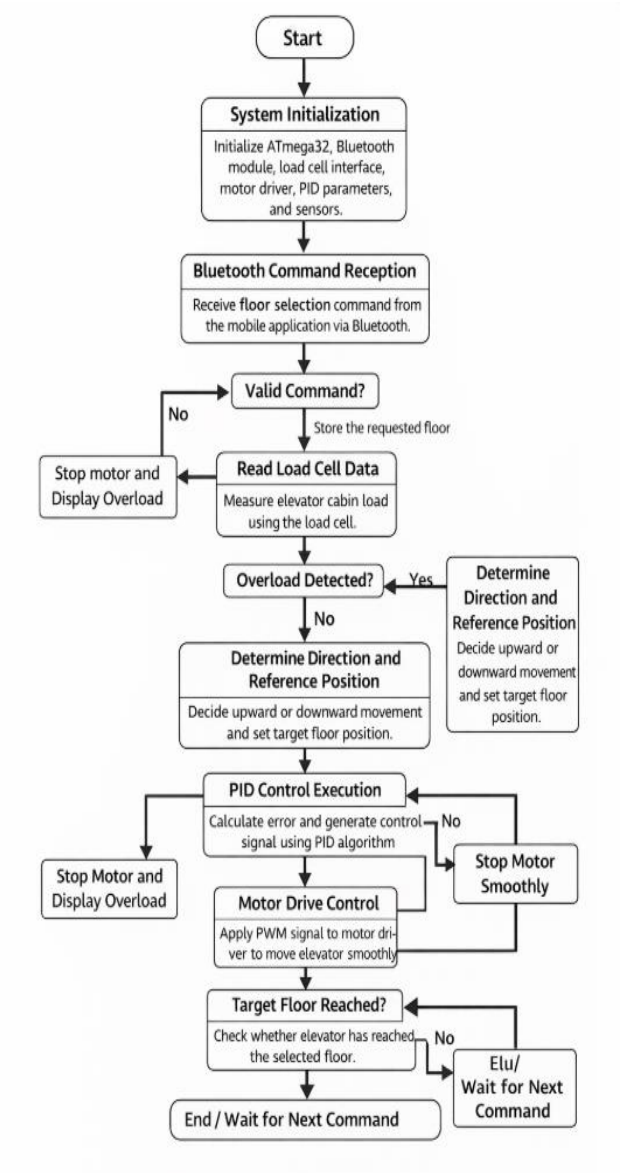

Fig4:Flowchart of the Bluetooth enabled elevator control

The figure 4 shows the flowchart, represents the operation of a Bluetooth-enabled elevator system controlled by an ATmega32 microcontroller. The system begins with initialization of all hardware modules, including the Bluetooth interface, load cell, motor driver, sensors, and PID parameters. Floor selection commands are received wirelessly from a mobile application via Bluetooth. The load cell continuously monitors the cabin weight to ensure safe operation; if an overload is detected, the motor is stopped immediately.

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4.HARDWARE OF THE ELVATOR CONTROL

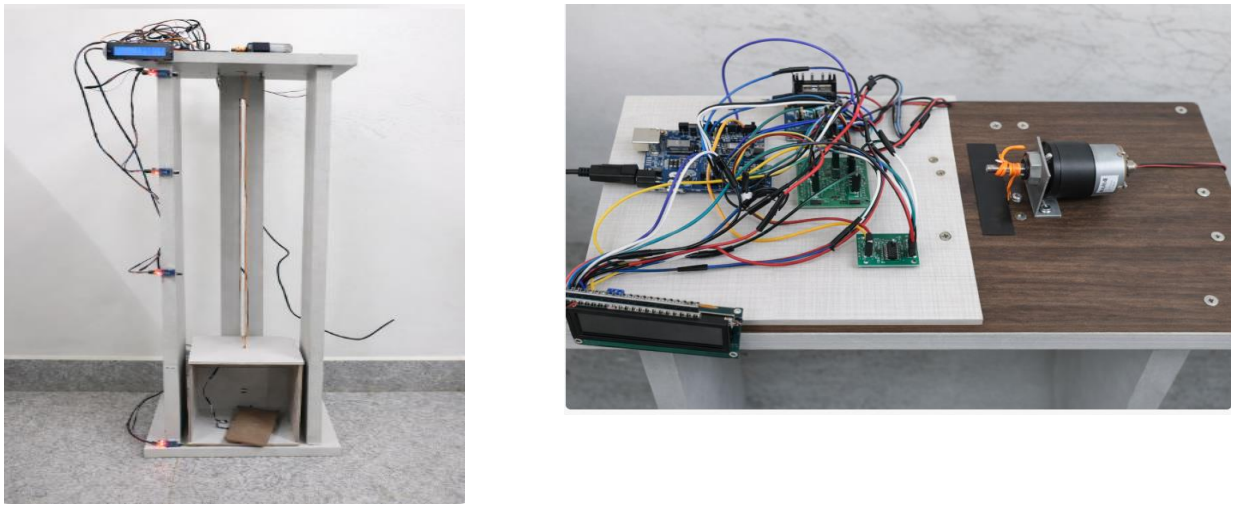

Fig 5: The hardware of prototype elevator control system controlled from the Bluetooth

The figure 5 shows the hardware implementation of the Bluetooth-enabled intelligent elevator control system integrates several components to ensure smooth, safe, and efficient operation. At the core of the system is a microcontroller unit (MCU), which serves as the central controller managing inputs, processing control algorithms, and driving outputs.

5. HARDWARE IMPLEMENTATION

The system uses a **Bluetooth module** to receive commands wirelessly from a mobile device, allowing users to select floors remotely. The microcontroller interprets these commands and initiates elevator movement accordingly.

To monitor the elevator's load, a **load cell sensor** is installed beneath the elevator platform. This sensor measures the weight of passengers or cargo and sends analog signals to the microcontroller. The system uses this feedback to prevent overloading and to optimize the elevator's motion parameters.

The elevator's movement is controlled using a **DC motor or stepper motor** coupled with an appropriate driver circuit. The microcontroller implements a **PID (Proportional-Integral-Derivative) control algorithm** to regulate the motor's speed and position precisely. The PID controller continuously adjusts motor inputs based on real-time feedback, ensuring smooth acceleration, deceleration, and accurate stopping at the selected floor.

Table 2. Hardware Component Specification.

Component	Model
Arduino	UNO
Motor Driver shield	LD298N
Bluetooth Module	HC-05
DC Motor	12V
IR sensor	HC-SR04
Power Supply	12/24 VDC
Loadcell	HX711
Display module	LCD

- **Microcontroller (Arduino Uno / Arduino Mega / ATmega328P)** – Core controller for elevator logic and PID implementation

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- **Bluetooth Module (HC-05 / HC-06)** – Wireless communication between mobile app and elevator controller
- **DC Motor / Gear Motor (12 V, 60 RPM)** – Drives the elevator cabin movement
- **Motor Driver Module (L298N / L293D)** – Controls motor direction and speed using PWM from controller
- **Load Cell (5 kg / 10 kg)** – Measures elevator cabin load
- **Position Sensors (Limit Switches / IR Sensors / Proximity Sensors)** – Detect floor positions and cabin limits
- **LCD Display (16×2 or 20×4)** – Displays current floor number and load status
- **Power Supply (12 V DC Adapter / SMPS)** – Provides power to motor and control circuit
- **Power Supply (12 V DC Adapter / SMPS)** – Provides power to motor and control circuit
- **Connecting Wires, PCB/Breadboard, Connectors** – Interfacing and assembly components

5.Result and Discussion

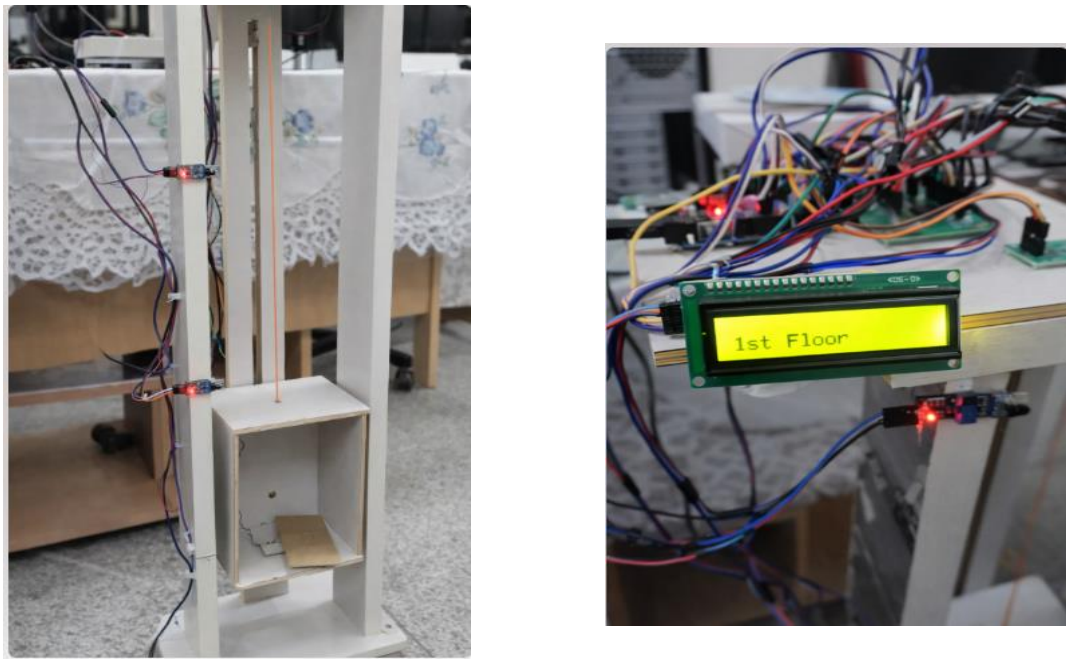

Fig. 5 :Output display of the elevator.

The figure 5 shows a prototype model of an intelligent elevator system used for experimental purposes. The structure represents a multi-floor elevator shaft with a movable cabin guided along vertical rails. Limit or position sensors are mounted at different floor levels to detect the cabin position accurately. A DC motor mounted at the top drives the elevator cabin using a pulley and rope mechanism. The control electronics, including the microcontroller and motor driver, are placed on the top platform. The LCD display at the bottom indicates the current floor position, which is shown as **" 1st FLOOR"** in the image

A PID controller is a robust and widely used control technique for regulating the speed of a DC machine. It works by minimizing the error between desired speed and the actual speed by adjusting the motor's input voltage. Proper tuning of the PID parameters ensures that the motor responds quickly and accurately to changes in the desired speed. The tuning of the PID controller to achieve optimal performance like low rise time, minimal overshoot, and fast settling time.

PID Control Law

The motor control signal is generated using a PID controller

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$$V_m(t) = k_p e(t) + k_i \int_0^t e(t) + K_d \frac{de(t)}{dt} \quad (2)$$

Kp = Proportional gain

Ki = Integral gain

Kd = Derivative gain

Vm(t) = Motor drive voltage

Load Cell Constraint Condition

$$W \leq W_{max} \quad (3)$$

The PID controller output is applied only when the elevator load is within safe limits:

- W≤Wmax, the motor command is forced to zero:
- Vm(t)=0

Motor Direction Logic

The direction of elevator movement is determined by the sign of the control signal

Direction ={ $up \quad e(t) > 0$ (4)

{down e(t)< 0 (5)

{ $stop\ e(t) = 0$ (6)

Complete Elevator System Model

Bluetooth→ATmega32→PWM→DCMotor→Gear→Elevator

Which mathematically becomes:

X(s)=Gmotor(s) Ggear(s) Gctrl(s) Ubt(s) (7)

where

- Gmotor(s) = motor transfer function
- Ggear(s)=r/N
- Gctrl(s) = PID/logic
- Ubt(s) = Bluetooth command

1.Identify PID Signals to Plot

- Setpoint (desired floor/position)

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- Actual position (sensor feedback)
- Error (Setpoint − Actual)
- PID output (motor control signal / PWM duty cycle)

2.Modify ATmega32 Firmware (Data Logging)

Setpoint,ActualPosition,PID_Output

printf("%d,%d,%d\n", setpoint, position, pid_output);
This data is transmitted through HC-05 to a PC or mobile device.

3.Receive Data on PC or Mobile

Mobile App

Use apps like:

- Serial Bluetooth Terminal
- Bluetooth Terminal HC-05

4. Typical PID Waveforms to Include in Report

- Setpoint vs Actual Position
- Overshoot and settling time
- Steady-state error
- PWM output vs time

prototype:

- The elevator needs to travel **2 feet total** to represent **4 full floors**.
- Each floor height in the model = **0.5 ft** (≈ 15.24 cm)
- Total vertical travel = **2 ft** (≈ 60.96 cm)

1. **Set physical track length** to 2 feet (61 cm) for the 4-floor model.
2. **Define floor positions** in code:
   - Floor 0 = 0 ft
   - Floor 1 = 0.5 ft
   - Floor 2 = 1.0 ft
   - Floor 3 = 1.5 ft
   - Floor 4 = 2.0 ft
3. **PID Setpoints**
   Use these positions as your reference input for the PID controller.

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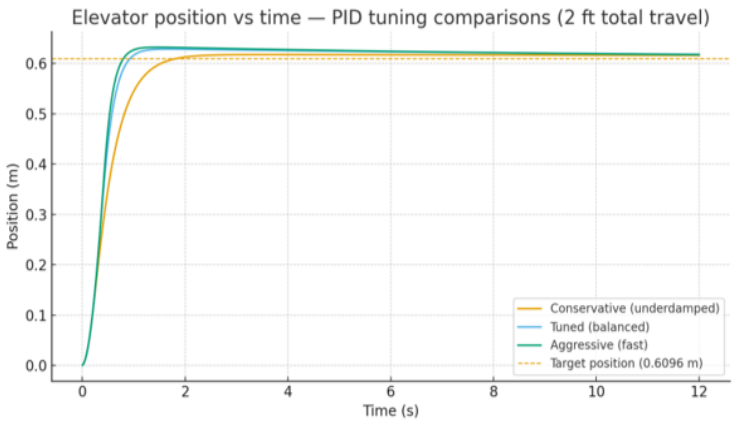

Fig 6:Elevator position vs Time response

The above Figure 6 represents the graph compares elevator position response for different PID tuning strategies over a total travel of 2 ft. The conservative tuning shows slower response with minimal overshoot, ensuring smooth but delayed positioning. The tuned (balanced) PID achieves the target position quickly with negligible overshoot, indicating optimal performance. The aggressive tuning reaches the target fastest but exhibits slight overshoot, which may cause passenger discomfort. Overall, the tuned PID provides the best trade-off between speed, stability, and accuracy for elevator applications..

Table 1: PID tuning result

Tuning	Kp	Ki	Kd	Rise Time (s)	Overshoot (%)	Settling Time (s)	Steady-state error (m)
Conservative (underdamped)	200	5	80	1.02	1.287	1.48	-0.00649
Tuned (balanced)	500	40	120	0.67	3.122	7.32	-0.00866
Aggressive (fast)	1200	120	220	0.61	3.689	7.61	-0.0082

The graph compares elevator position respo**nse** for different PID tuning strategies over a total travel of 2 ft. The conservative tuning shows slower response with minimal overshoot, ensuring smooth but delayed positioning. The tuned (balanced) PID achieves the target position quickly with negligible overshoot, indicating optimal performance. The aggressive tuning reaches the target fastest but exhibits slight overshoot, which may cause passenger discomfort. Overall, the tuned PID provides the best trade-off between speed, stability, and accuracy for elevator applications.

Conservative (Underdamped) Tuning

- **Low Kp and Ki, moderate Kd** result in smooth system behavior.
- **Rise time (1.02 s)** is the slowest, indicating a gradual response.
- **Very low overshoot (1.287%),** which is desirable for elevator safety.
- **Fast settling time (1.48 s)** with minimal oscillations.
- **Small steady-state error (-0.00649 m)** shows good position accuracy.

  Best for **safe, smooth elevator motion** with minimal vibration.

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Tuned (Balanced) Control

- **Moderate Kp, Ki, and Kd** provide a compromise between speed and stability.
- **Faster rise time (0.67 s)** than conservative tuning**.**
- **Higher overshoot (3.122%),** acceptable but noticeable**.**
- **Longer settling time (7.32 s) due to oscillations before stabilizing.**
- **Slightly higher steady-state error (-0.00866m).**

Aggressive (Fast) Tuning

- **High Kp, Ki, and Kd** produce a very fast response.
- **Fastest rise time (0.61 s)**.
- **Highest overshoot (3.689%)**, which may cause discomfort.
- **Longest settling time (7.61 s)** due to increased oscillations.
- **Steady-state error remains small (-0.0082 m)**.
- Conservative tuning is best for passenger safety and comfort.
- Balanced tuning offers a trade-off between speed and smoothness.
- Aggressive tuning, although fast, is not recommended for elevator systems due to overshoot and longer settling time

6. CONCLUSION

The Bluetooth-enabled intelligent elevator control system with load cell and PID control successfully combines wireless communication, precise load monitoring, and advanced motor control to enhance elevator performance. By integrating the load cell, the system ensures safe operation by preventing overloading, while the PID controller provides smooth and accurate movement between floors. The use of Bluetooth technology allows convenient remote floor selection, improving user experience. Overall, this hardware implementation demonstrates how modern sensors and control techniques can be effectively applied to traditional elevator systems, increasing safety, efficiency, and reliability. The design is scalable and can be adapted for various elevator sizes and building requirements. Future enhancements may include more sophisticated algorithms and additional safety features to further optimize performance.

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