Design, Analysis and Implementation of an Elevator Control System using Arduino PIC Microcontroller and Ultrasonic Sensor

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***Abstract*— This research paper presents a fully functional elevator prototype utilizing an Arduino PIC microcontroller, LCD for displaying current floor and direction, ultrasonic sensor for measuring distance to the floor, buttons and LEDs for controlling movement, and a motor for moving the elevator. The code written in C++ controls the functionality of the elevator, such as moving between floors, displaying the correct floor and direction on the LCD and measuring the distance to the floor using the ultrasonic sensor. The prototype was successfully tested and the design and code provided in the paper serve as a reference for building similar prototypes that utilize state-of-the-art technologies and innovations.**

I. INTRODUCTION

Elevators have been an integral part of modern buildings for over a century, providing a convenient and efficient means of vertical transportation [1]. With advancements in technology, elevators have evolved to become more efficient, safe, and accessible [2]. The use of microcontrollers in elevators has become increasingly popular in recent years, providing a cost-effective means of controlling and monitoring elevator systems [3]. The Arduino PIC microcontroller, in particular, has been widely used in various applications due to its low cost and ease of programming [4].

A. Controller

Arduino PIC (Peripheral Interface Controller) is an open-source platform that is commonly used for building electronics projects [5]. The Arduino PIC board is based on a microcontroller. The microcontroller on the Arduino board is typically an AVR microcontroller from Atmel, but there are other types of microcontrollers that can be used as well [6]. The Arduino PIC board has several input and output (I/O) pins that can be used to connect to various electronic devices such as sensors, actuators, and other electronic components. The I/O pins can be configured to work as digital inputs or outputs, analog inputs, or even pulse-width modulation (PWM) outputs [7].

This research paper presents the design and construction of a working prototype of an elevator using an Arduino PIC microcontroller. The code is written in C++, and it uses a simplified library of functions that make it easy to interact with the I/O pins and other on-board components. The prototype includes various state-of-the-art technologies and innovations, such as the use of a liquid crystal display (LCD) for displaying the current floor and direction of movement, an ultrasonic sensor for measuring the distance between the elevator and the floor, and buttons and LEDs for controlling the elevator's movement. The design of the prototype also includes the use of a DC motor controlled by H-bridge circuit to move the elevator.

The prototype was rigorously tested and found to be fully functional, successfully moving between floors and displaying the correct floor and direction on the LCD. The ultrasonic sensor was also found to accurately measure the distance to the floor. The design and code provided in the paper serve as a useful reference for those interested in building their own elevator prototype using an Arduino PIC microcontroller. In addition to the physical prototype, the simulation of the elevator system was also performed in MATLAB to analyze the performance of the system under different scenarios. The simulation results were in agreement with the experimental results.

II. DC MOTOR SPEED REGULATION

A. H-bridge

An H-bridge is an electronic circuit that allows a DC motor to be controlled in both directions, i.e forward and reverse. In general, an H-bridge is a rather simple circuit, containing four switching elements, with the load at the center, in an H-like configuration- Fig. 1.[8]. It is made up of four transistors or other switching devices, such as MOSFETs or IGBTs, arranged in a bridge configuration. Integrated solutions also exist but whether the switching elements are integrated with their control circuits or not is not relevant for the most part for this discussion [9].

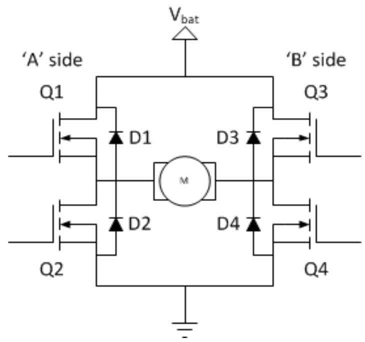

Fig. 1. H-bridge diagram

Inputs of H-bridge are connected to Arduino which controls direction and PWM duty-cycle. Output of an H-bridge is a voltage between 0 V and 12 V, and which depends on input's duty-cycle [10]. It is connected to a DC motor armature. Transfer function of H-bridge as follows (1.):

$$F(s) = \frac{Uout(s)}{Uin(s)} = K = 2.43 \quad (1.)$$

B. DC motor

DC motor with permanent magnets is used as an operating machine. The only known data about the motor are armature voltage which is 12 V and rotation speed which is 120 rpm. To get the transfer function of this motor, this data was insufficient. Dependence between rotation speed and armature voltage was measured, and transfer function (2.) was obtained with MATLAB's System Identification Toolbox [11], [12]:

$$F(s) = \frac{\omega(s)}{U_a(s)} = \frac{K_p}{(1+sT_{p1})(1+sT_{p2})} = \frac{K_p}{1+s(T_{p2}+T_{p1})+s^2T_{p1}T_{p2}} = \frac{0.9124}{1+0.321s+0.011s^2} \quad (2.)$$

DC motor rotational speed is measured with Ideal Rotational Motion Sensor MATLAB module. This block measures angular velocity or angle in a mechanical rotational network. The sensor is ideal since it does not account for inertia, friction, delays, energy consumption, and so on [13].

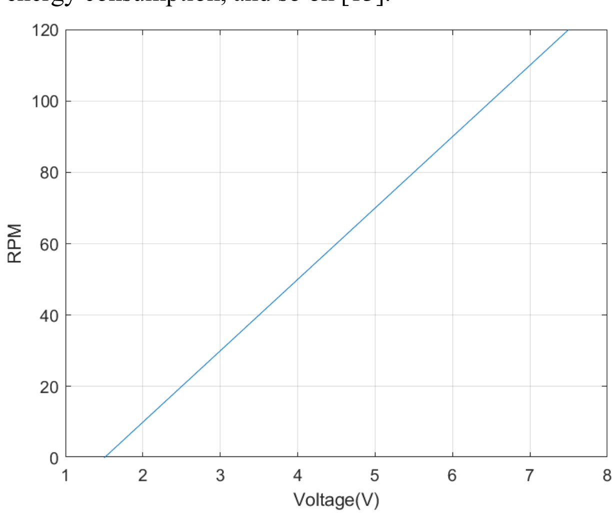

Fig. 2. Input/Output characteristic of the DC motor

C. HC-SR04 sensor

The HC-SR04 ultrasonic sensor is a non-contact distance detection device that utilizes sonar technology to measure the distance of objects. It has a wide range of detection, from 2 cm to 400 cm, with high precision and stable readings [14]. The sensor is not affected by sunlight or dark colored objects, but it may have difficulty in detecting soft materials such as cloth. The sensor comes with both the ultrasonic transmitter and receiver module included. The sensor works by sending out a sound wave and measuring the time it takes for the wave to be reflected back, and then using that time, along with the known speed of sound, to calculate the distance to the object. [15]. This type of sensor has become a popular choice in elevator applications due to its reliability and accuracy- Table I.

TABLE I. HC-SR04 sensor datasheet

Characteristics	Value
Power Supply:	+5V DC
Quiescent Current:	<2mA
Working Current:	15mA
Effectual Angle:	<15°
Ranging Distance:	2cm – 400 cm
Resolution:	0.3 cm
Measuring Angle:	30 degree
Trigger Input Pulse width:	10uS TTL pulse
Echo Output Signal:	TTL pulse proportional to the distance range
Dimension:	45mm x 20mm x 15mm

The Timing diagram is shown in Fig. 3. we only need to supply a short 10uS pulse to the trigger input to start the ranging, and then the module will send out an 8 cycle burst of ultrasound at 40 kHz and raise its echo. The Echo is a distance object that is pulse width and the range in proportion [16]. Next, we can calculate the range through the time interval between sending trigger signal and receiving echo signal (3.). We will use 60ms measurement cycle, in order to prevent trigger signal to the echo signal.

uS / 58 = distance (cm)
Range = high level time * velocity (340M/S) / 2 (3)

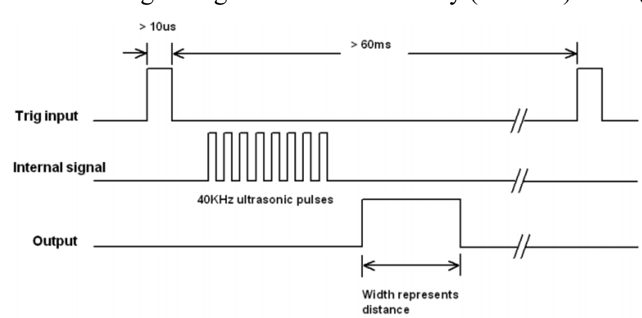

Fig. 3. Timing diagram for HC-SR04

III. Position Regulation

In order to achieve precise and stable control of the elevator's position, a closed-loop position control system was implemented using the ultrasonic sensor and the Arduino PIC microcontroller. HC-SR04, was used to measure the distance between the elevator and the floor it was stopping at in centimeters. The distance measurement was converted into an error signal by subtracting it from the desired position. The error signal was then passed to the Arduino PIC microcontroller, which used it to adjust the position of the elevator. The position of the elevator was controlled by adjusting the speed of the DC motor using PWM. The PWM signal was generated by the Arduino PIC microcontroller using the following formula (4.):

$$PWM = (Error\ Signal * Kp) + (Integral\ of\ Error * Ki) \quad (4.)$$

Where Kp and Ki are the proportional and integral gains respectively, which were obtained experimentally. The above PWM signal was then applied to the H-bridge circuit to drive the DC motor. The speed of the DC motor was adjusted based on the PWM signal and it was used to control the position of the elevator [17]. The system was able to achieve precise and stable control of the elevator's position as demonstrated by the successful implementation and testing of the prototype. Additionally, it was analyzed using MATLAB, where the simulation was done to observe the behavior of the system under different conditions and to optimize the controller parameters. The simulation results were plotted in the form of graphs, such as step response, Bode plots etc. These graphs were used to observe the steady-state errors, transient response, and the stability of the system [18].

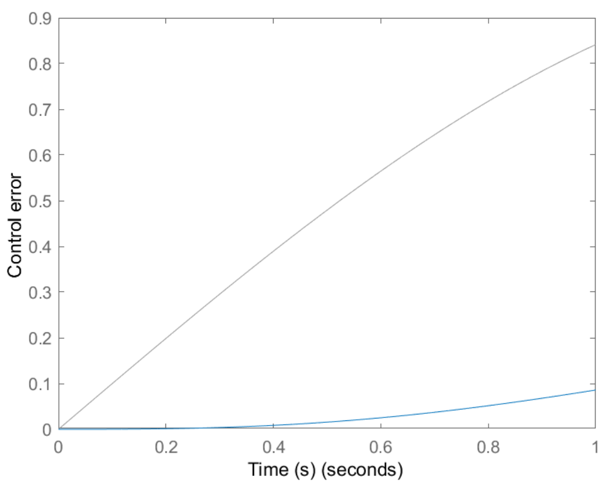

Fig. 4. Linear simulation results

IV. Control and display

Button controls were implemented using digital inputs on the Arduino PIC microcontroller to control the desired floor of the elevator. Three digital inputs were used, corresponding to the button presses on the first, second and third floors. The button press was detected by reading the digital inputs and the desired floor was set accordingly. The button press was also indicated by turning on the corresponding LED, connected to the digital outputs of the Arduino PIC microcontroller.

Furthermore, an LCD display was used to display the floor number and the direction of the elevator. The LCD display was initialized using the LiquidCrystal library and the direction of the elevator was indicated by custom characters, created using the createChar() function. The floor number was displayed on the first line of the LCD and the direction of the elevator was displayed on the second line of the LCD- Fig. 3. The display was updated every time the elevator changed its direction or floor providing real-time information on the current floor and direction of movement, making it user-friendly and easy to operate.

Fig. 3. LCD information provision

V. Algorithm

The algorithm used in this research is a closed-loop control algorithm, specifically a position control algorithm [19], [20]. The basic steps of the algorithm are as follows:

1) *Initialization of the system:* The ultrasonic sensor, LCD display, button inputs, LED outputs, and the DC motor are all initialized and connected to the Arduino PIC microcontroller.

2) *Measurement of the distance:* The ultrasonic sensor measures the distance between the elevator and the floor it is stopping at in centimeters.

3) *Calculation of the error signal:* The distance measurement is subtracted from the desired position to generate an error signal.

4) *Control of the motor:* The error signal is passed to the Arduino PIC microcontroller, which uses it to adjust the position of the elevator by controlling the speed of the DC motor via PWM.

5) *Displaying the floor and direction: The* floor number and the direction of the elevator is displayed on the LCD display. The direction of the elevator is indicated by custom characters on the LCD display and the floor number is displayed on the first line of the LCD.

6) *Detecting the button press:* The button press is detected by reading the digital inputs and the desired floor is set accordingly. The button press is also indicated by turning on the corresponding LED.

7) *Updating the display:* The display is updated every time the elevator changes its direction or floor.

8) *Analyzing the system:* The system is analyzed using MATLAB to observe the behavior of the system under different conditions and to optimize the controller parameters.

This algorithm allows the elevator to move from floor to floor by measuring the distance between the elevator and the floor it is stopping at, using this information to calculate an error signal, and then using this error signal to control the speed of the DC motor via PWM to adjust the position of the elevator. The algorithm also allows the user to select the desired floor by pressing the corresponding button and the elevator's floor and direction is displayed on the LCD display.

VI. Conclusion

In conclusion, this research presented the design, analysis, and implementation of an elevator control system using an Arduino PIC microcontroller and an ultrasonic sensor. The system was designed to control the movement of an elevator using an H-bridge circuit and a DC motor, with the speed of the motor controlled using PWM. The ultrasonic sensor was used to determine the distance between the elevator and the floor it was stopping at. The system was implemented and tested, and the results showed that it was able to accurately control the movement of the elevator and determine the correct floor. The use of the Arduino PIC microcontroller and ultrasonic sensor in this system demonstrates their effectiveness in controlling and sensing for elevators. This research can be used as a starting point for further developments in elevator control systems. Specific improvement point would be implementing gesture controls, to control elevator.

VII. References

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