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DEVELOPMENT OF AN AUTOMATIC DOOR CONTROLLER FOR A SMART BUILDING

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ABSTRACT

Smart building and Building automation systems (BAS) have gained popularity in recent times. An automatic system furnishes comfort and saves time. The paper discusses a smart system applied to a building. The work uses a microcontroller ATmega 328P to design an automatic door controller. The design employs a passive infrared sensor to sense the approaching human towards the door. It incorporates an ultrasonic sensor to calculate the distance between it and the body. As the distance is between 10cm and 60cm, a control signal is initiated from FMOTOR (pin8) to drive an electronic switch having a relay as load. A close door signal from RMOTOR (pin9) also closes the sliding door if the conditions are not met. Both switches have relays as their loads and their contact sets control a geared 12V DC motor in forward (Door open) and reverse (Door Close) rotational directions. Operational status is displayed on a 16 by 2 Liquid crystal display (LCD) with the sound of a one-second, 1 kHz audio tone burst. The codes are written using C++ programming language while compilation is done on an Arduino integrated development environment (IDE). In order to validate the design, it was simulated on Proteus 8.

KEYWORDS: Automation; Smart building; Design; Door; Sensors; Simulation; Microcontroller

INTRODUCTION

The hallmark of the modern world is automation systems (Rabbani & Foo, 2022). Daily, innovations are growing in various improvement iterations in countries worldwide (Akinwole, 2020). The aspects of smartening and sustainability of buildings are receiving the attention of engineers and technologists in all disciplines (Selvaraj, 2023). Today, electronic and electrical devices can be controlled from remote locations anywhere on the globe, also some applications allow monitoring of buildings for security purposes through the usage of 360º viewing cameras; circuit breakers incorporating energy metering can be controlled and monitored on mobile phones. Parameters like power consumption in watts, energy usage in kilowatt-hours, and current drawn are monitored by homeowners from their places of work. These types of breakers deploy dashboards for setting up operating thresholds, for example, ambient temperature, leakage current, overvoltage, and under-voltage; in the event of readings rallying outside set points, the breakers switch off. These bouts of trips are usually logged on the alarm records page. If the recloser function is activated, every tripping session will be reclosed after seconds set by the user. Most smart buildings have the functions mentioned above, home devices are controlled through wireless connections, lighting units can be controlled automatically by deploying occupant sensors in rooms, and if no one is present, lighting units will be automatically switched off. The same also goes for heating, ventilation, and air conditioning systems (HVAC). It has been established that lighting and HVAC systems are the major areas through which energy is consumed in buildings (Kim et al, 2022). The Energy Information Bureau based in Washington DC discloses that

about 75% of energy consumption in the United States was done in buildings while the remaining 25% is consumed in the transportation sector (Powers & Saad, 2022). Smart technologies make lives comfortable for users. Gates can be opened automatically as a car approaches it, or controlled wirelessly at the depression of a pushbutton. This paper proposes a smart device that opens a sliding door as someone approaches it; the microcontroller-based system incorporates two sensors, one, a passive infrared sensor (PIR) (Rochas et al., 2019) that senses the approaching human movement, and two, is an ultrasonic sensor that measures the distance between the door and the person; the two situations are ANDed by using C programming language. The result is the opening of the door (Pandini et al., 2024) with the sounding of a tone for a second while operational status is displayed on a 16 × 2 liquid crystal display (LCD).

MATERIALS AND METHOD

The heart of the system is a microcontroller implemented with an 8-bit ATmega 328P (Figure 1). Passive infrared and ultrasonic sensors are used as intelligent sensors that sense human presence and determine his or her proximity to the door. Coding is achieved using C programming language (Akinwole, 2020), the code using IF, AND, OR and relational functions to produce a HIGH of +5V when true. The latter is used to drive an electronic switch achieved with NPN bipolar transistor 2N2222 having a 12V relay as load (Akinwole & Oladimeji., 2018). An untrue state drives another electronic switch. The relay's contact sets are wired in series with a DC motor that provides a rotational motion for the door mechanism. A switch provides forward rotation while the other furnishes a reverse motion, an action that depends on which one receives signals from the microcontroller. Some programming syntaxes used are #define to define the pins, pinMode, to determine its function whether it is an INPUT or OUTPUT, digitalRead and digitalWrite, to read and write digital values on and to pins respectively.

Liquid Crystal LCD is used to assign pins to liquid crystal display. Hex files produced after compilations of codes are used for simulation on Proteus 8 professional.

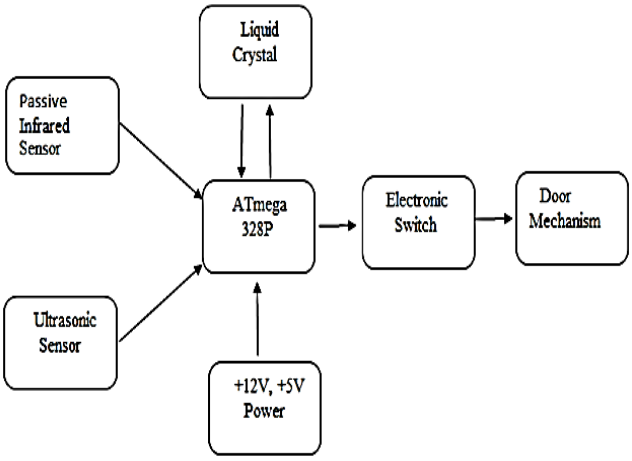
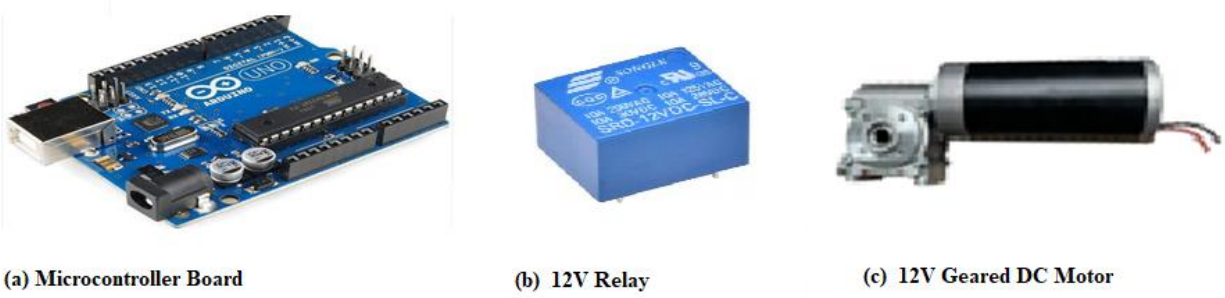


Figure 1: The system's block diagram

Microcontroller

A microcontroller is a computer on a single chip. It incorporates its processor unit, read only memory (ROM), random access memory (RAM), and other peripheral units. As a result of developments in embedded systems technologies, microcontrollers being the heart of those innovations, have continued to receive the attention of engineers and researchers alike. They have the advantages of being cheap and small in size. They can be programmed with ease and are easy to learn. Common types of microcontrollers include peripheral interface controllers {PIC), advanced RISC machine (ARM), and Alf and Vagards RISC processor (AVR). Another is 8051 microcontrollers created by Intel in 1981 (Embedded Schools, 2019). Microcontrollers are also classified according to their number of bits, common ones are 8-bit, 16-bit, and 32-bit types.



(a) Microcontroller Board (b) 12V Relay (c) 12V Geared DC Motor

Figure 2: Microcontroller board, relay, and DC motor

This design incorporates an ATMega 328p board (Figure 2a) which incorporates a programmer, a power supply unit, and a crystal oscillator. It is of AVR types developed by Microchip. It has 8 - bits, flash memory of 3 kilobytes, static random access memory (SRAM) of 2 kilobytes, and 1 kilobyte of electrically erasable programmable read only memory (EEPROM). It has a clock speed of 16 MHz and is a reduced instruction set computing type (RISC) with 23 general-purpose I/O (GPIO) pins (Microchip, 2023). The pins are recognized based on the actions allocated to them and specified by programs. For example, pinMode (3, OUTPUT) assigns pin 3 as an output pin.

Ultrasonic Sensor

One of the design requirements of this innovation is to calculate the distance between the door and the person approaching it. As a result of this, an ultrasonic sensor (HC-SR04) is used (Figure 3a). The sensor intelligently measures the distance of a target object by transmitting an ultrasonic wave to hit the target object and calculates the distance between the two points by determining the to and fro times (Tutorial Point, 2020). A measuring section is initiated by putting a HIGH (+5V) at its trig. Pin. An echo pin indicates a received signal. The process is embedded in the code as explained below:

```
digitalWrite (trigPin, LOW); //take trig pin low
delayMicroseconds(2);// the trig pin should be low for 2 microseconds
digitalWrite(trigPin, HIGH);// take the trig pin to HIGH (+5V) level
delayMicroseconds(10);// trig pin to be at the HIGH level for 10 microseconds
digitalWrite(trigPin, LOW);// take the pin to low again
duration = pulseIn(echoPin, HIGH); //Measure the HIGH period and assign the time to period
distance = (duration/2) / 29.1;// calculate the distance
Serial.println(distance);// print the distance on a serial printer
Delay (100); // delay for 10 milliseconds
```

Passive Infrared Sensor

The passive infrared sensor is used to detect the motion of a person within its range. The type used is HC-SR501. It furnishes means of adjusting delay and sensing range, the latter has a maximum range of 7 meters. The input DC supply ranges from 4.5 to 20 VDC. The design uses 5VDC voltage that is sourced from the microcontroller board (Utmel Datasheet, 2023).

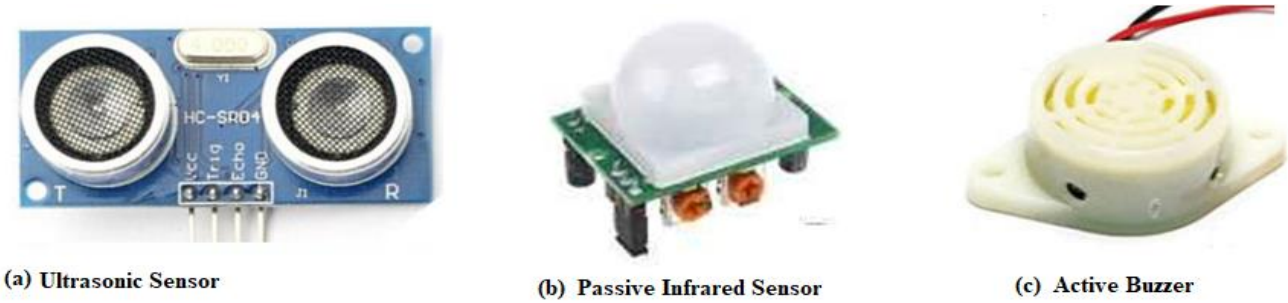


Figure 3: Sensors used and an active buzzer

Forward and Reverse DC Motor Control

A typical DC motor commonly used for an automatic door opener is of 12V, 24V, 36V, and 48V geared brushless types. Other ones have brushes, in this design work, a geared DC motor with a permanent magnet with open drip protection is adopted. It has various applications ranging from fans to automatic doors. It comprises a gearbox for speed reduction purposes. It is designed to operate a sliding door that travels on a friction-free rail system. For a door-closing period, the motor is forward-biased biased while an opening process involves biasing it in the reverse direction (Figure 4).

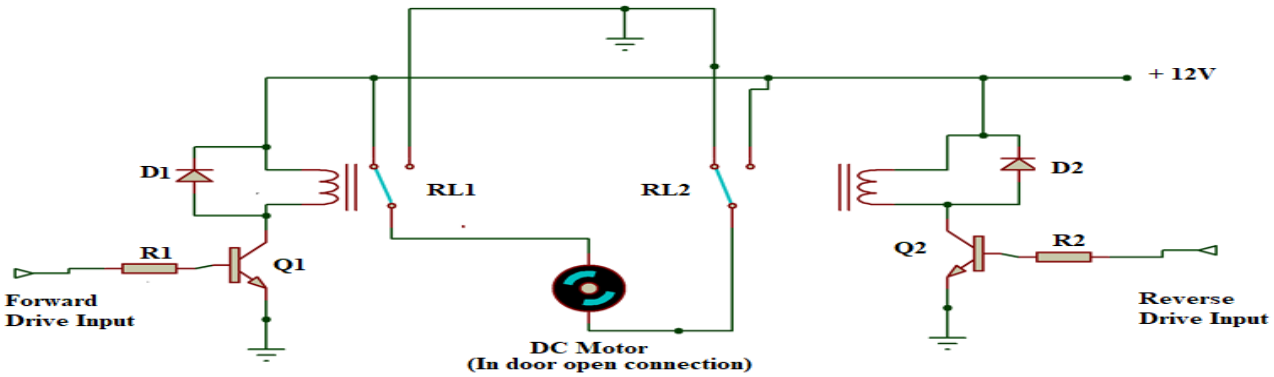


Figure 4: DC motor forward and reverse with switching system

Programming

With the aid of flowchart in figure 5 which diagrammatically represent the order of activities used to design the system. The coding using C++ programming language is done on an Arduino integrated development environment (IDE) (Arduino, 2023). To display the status of control actions, a liquid crystal display unit is used. The syntax is Liquid Crystal LCD (RS, EN, D4, D5, D6, D7) for a four-pin mode. In an eight-pin mode, data lines D0-D7 are used. In this case, the RS pin which selects the register is hooked to pin 4, Enable (EN) pin is 5. Data lines D4, D5, D6, and D7 are connected to pins 10, 11, 12 and 13 respectively. Ultrasonic pins are Trig and Echo pins, while a trig pin serves as an input, echo represents output; both are named trigPin and echoPin respectively. Buzzer is connected to buzzerPin, (pin 7). Motor forward and reverse control signals are obtained from pins 8 and 9 respectively. A HIGH (+5V) signal after human detection is obtained at HpirSensor realized with pin2. The logical expression used to operate the door is an IF, else statement:

if((distance>=60||distance<=10)&&(vald=LOW
)),

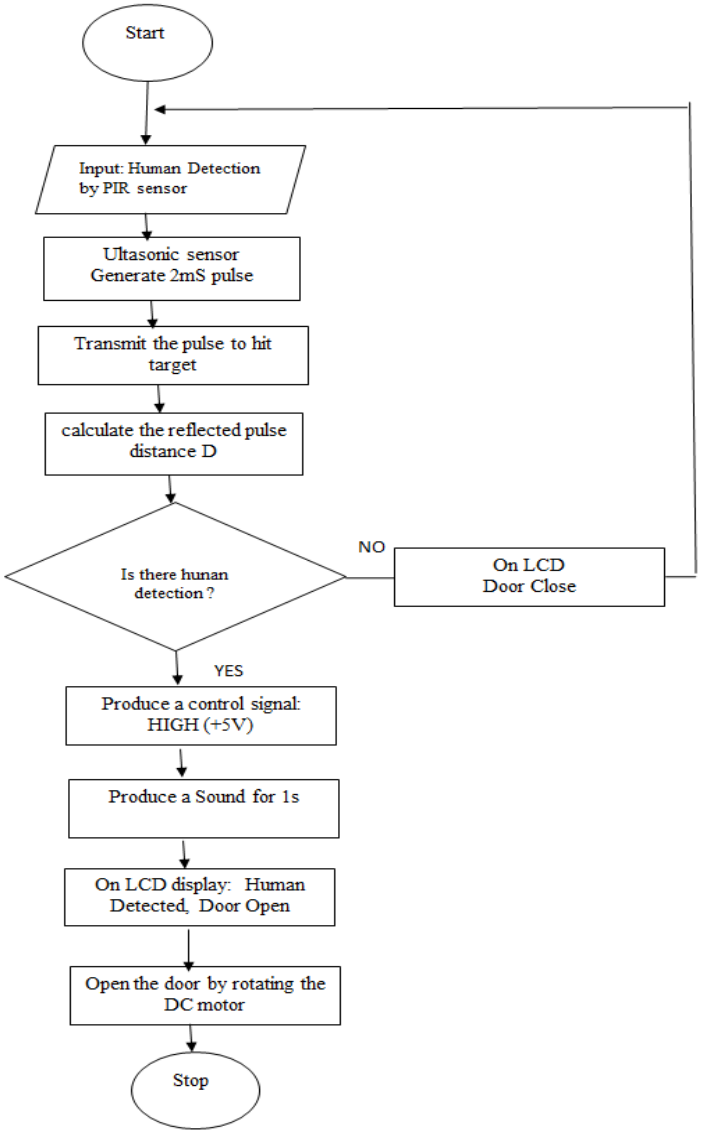


Figure 5: The design's flow chart

the door should remain closed **else** it should be opened. The following are the setup codes.

```
#include <LiquidCrystal.h>
#include <Wire.h>
Liquid Crystal lcd(4,5,10,11,12,13);

#define trigPin 3
#define echoPin 6
#define buzzerPin 7
#define FMOTOR 8
#define RMOTOR 9
#define HpirSensor 2
int vald =0;
 void setup()
{
Serial.begin (9600);
pinMode(trigPin, OUTPUT);
```

```
pinMode(echoPin, INPUT);
pinMode(buzzerPin, OUTPUT);
pinMode(FMOTOR,OUTPUT);
pinMode(RMOTOR,OUTPUT);
pinMode(HpirSensor, INPUT);

lcd.begin(16,2); // for 16 X 2 LCD module
lcd.setCursor(0,0);
lcd.print("SMART DOOR");
lcd.setCursor(0,1);
 lcd.print("CONTROLLER");
  delay(1000);
}
```

Simulation on Proteus 8 Professional

Proteus software was produced by Labcenter Electronics to design, draw, and simulate electronics circuits by Engineers, technicians, and students using their personal computers or laptops (Labcenter Electronics, 2023). Apart from drawing and designing circuits, it is also been deployed to create printed circuit board (PCB) layouts. Figures 6 and 7 show the Proteus schematic capturing window. PIR sensor is manually simulated with a single-pole single-throw switch that has its lower end connected to microcontroller board pin 2 (HpirSensor) and dropped down to the ground with a 10kΩ resistor. The switch's other end is connected to +5V. As it closes, a HIGH (Figure 6) is applied to the pin, thus indicating a human motion has been sensed.

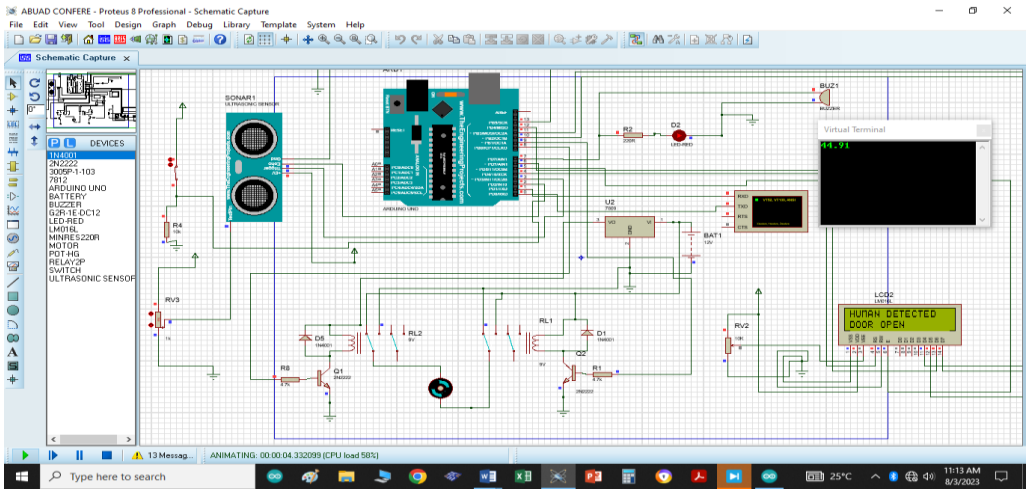


Figure 6: Door open switching of DC motor

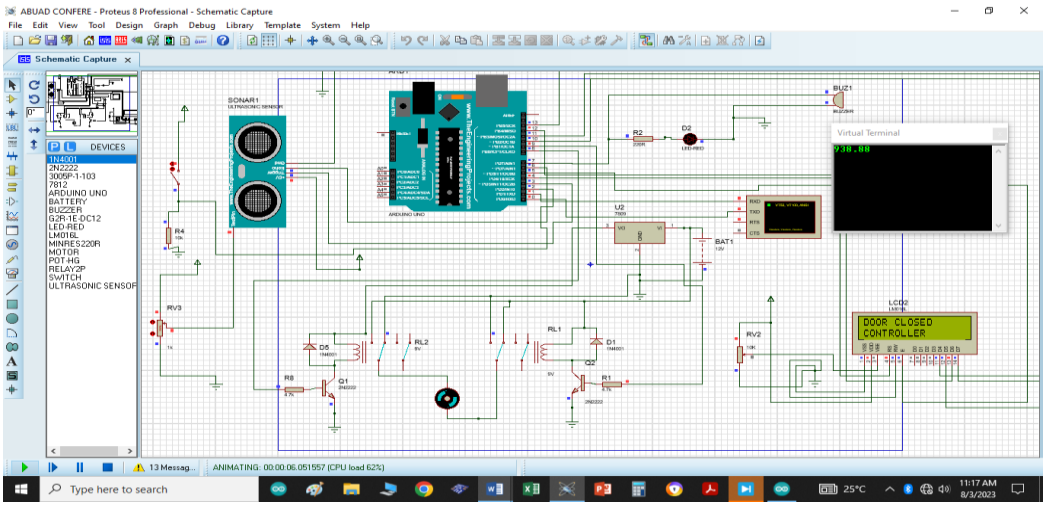


Figure 7: Door close switching of DC motor

RESULTS AND DISCUSSION

The result of the design is as summarized in Table 1 below, any distance outside the 10cm to 60cm range, the door remains closed while targets within the range allow the door to open. In other words, the signal at each switch input is opposite of the other. For a switch to operate, it must have a HIGH (+5V) input (Akinwole & Oladimeji, 2018). The latter saturates its transistor, thus taking its collector to be at LOW (0V) potential. Hence, the LOW at the collector applies 12V across the operating coil of the 12V relay, an act that energizes it with the resultant operation of its contact set.

Table 1: Target distance, electronic switches drive, and door status

Distance (cm)	Q1 Input	Q2 Input	Q1 Collector	Q2 Collector	Door
5	Low	High	High	Low	Closed
10	High	Low	Low	High	Opened
20	High	Low	Low	High	Opened
30	High	Low	Low	High	Opened
40	High	Low	Low	High	Opened
50	High	Low	Low	High	Opened
60	High	Low	Low	High	Opened
70	Low	High	High	Low	Closed
80	Low	High	High	Low	Closed
90	Low	High	High	Low	Closed
100	Low	High	High	Low	Closed

CONCLUSIONS AND RECOMMENDATIONS

The work has been able to systematically explain the development of an automatic door controller for a smart building. It is of note that the door will only open if there is human movement and the distance of the sensed person is within 10cm to 60cm. To guarantee continuous operation, the power supply must be available at all times; to ensure the foregoing, a dedicated 12V deep cycle battery should be installed for the door system while PV installation be introduced to ensure that the battery is charged always. Free movement of the sliding door in its rail must be ensured by deploying friction-free rollers capable of bearing the weight of the door. Installation of a DC circuit breaker will allow disengagement of the door system in case of mechanical overload.

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