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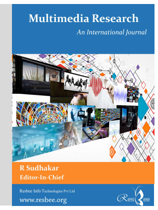

Design and Construction of a Motion-Based Automatic Door Opener with Metal Detector

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Abstract: This project work presents a motion-based automatic door opener with a metal detector. With the challenges encountered by physically challenged people to access doorways, the stressful task of opening and closing doors, and the activities of criminals carrying weapons made of metals into public places like supermarkets, banks, etc, This work is designed to provide easy access through doorways and prevent entry with metals which may be harmful. This is achieved using a passive infrared (PIR) sensor which is used to sense the presence of a human being through the person's body heat. The information from the PIR sensor is fed to a microcontroller which gives an output to the servo motor to rotate and move the door open and close. The programming of the microcontroller is done in such a way that the door opens only when the PIR sensor is 'high' indicating human detected and the metal detector is 'low' indicating no metal detected and as such entry with metal is prevented automatically.

Keywords: Microcontroller, Servo Motor, Passive Infrared, LCD, Direct Current

Nomenclature

Abbreviation	Expansion
PIR	Passive Infrared
IR	Infrared
DC	Direct Current
RPM	Rotations Per Minute
LCD	Liquid Crystal Display
LDR	Light Depending Resistor
RF	Radio Frequency
AC	Alternating Current
AWG	American Wire Gauge

1. Introduction

1.1 Background of the Study

The motion-based automatic door opener is a door or gateway that opens without any manual help when it senses the presence of a human being around it. It works through motion detection of people close to the door and gives an output according to the circuit. Motion detection is achieved with a PIR sensor which detects the motion of a person using the person's body heat. A live body emits some energy and this energy is sensed by the PIR sensor within its range and sends a command to open the door. PIR sensors detect the change in the IR level emitted by humans. The presence of the human body creates a sudden change in the IR profile of the surroundings that is sensed by the sensor [11]. This sensing signal is fed to a microcontroller to operate a servo motor which drives the door open and close.

A servo motor is an electrical device that can push or rotate an object with great precision**.** It is made up of a small DC motor that runs on electricity and spins at high RPM but put out very low torque. An arrangement of gears takes the high speed of the motor and slows it down while increasing the torque. It also consists of a positional sensor on the final gear connected to a small circuit board. This sensor tells the circuit board how far the servo output shaft has rotated. The electric input signal from the microcontroller is also fed into this circuit board. The electronics on the circuit board decode the signal to determine how far the user wants the servo motor to rotate. It then compares the desired position to the actual position and decides which direction to rotate the shaft so it gets to the desired position.

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This project proposes a system that makes passing through doors easy as the door opens automatically when someone approaches the door. It also incorporates a metal detector to step up the security of the system. If a person passing through the door is with a metal, the metal detector outputs a 'high' and the microcontroller would not give a command to the servomotor to open the door. It sends a signal to the detector circuit which then triggers a buzzer on. The door opens only when the PIR sensor is 'high' (human presence is detected) and the metal detector is 'low' (no metal detected). Different kinds of metal detectors are used to detect the presence of metals nearby (Handheld metal detectors, walkthrough metal detectors, and ground search metal detectors). Metal detectors work based on the principle of electromagnetic induction. It is made up of an oscillator producing an alternating current that passes through a coil thereby producing an alternating magnetic field. When a piece of electrically conductive metal is close to the coil, eddy currents will be induced in the metal which produces a magnetic field of its own. This change in magnetic field due to the metal object is detected as an increase in current in the oscillator which is fed to turn on a buzzer. This motion detection principle can also be applied in the activation of street lights, or indoor lights in walkways and staircases. It is also applied in a bugler alarm system that alerts a homeowner or security personnel when it detects the motion of an intruder.

1.2 Statement of the Problem

Work and business places like banks, shopping malls, supermarkets, and hotels require a large number of people moving in and out for their business transactions and entail frequent opening and closing of doors and gates which can be very tedious, energy-consuming, stressful and monotonous and may result in traffic and congestion. This sometimes requires hiring a person whose sole job will be to open and close doors for passersby. Physically challenged persons may also find it difficult to access doors and gateways that are being opened and closed manually. With the increase in criminal activities across the world, it is pertinent that gunmen, knifemen, and kidnappers are prevented from gaining access to banks, hotels, supermarkets, airports, and other business places. Many of the deadly weapons used by these societal miscreants are made from the combination and synthesis of metallic materials. One way to stop these hardened and determined criminals is the installation and use of metal detectors in these strategic public places [8].

This project proposes a mechanism for solving these problems by using the motion detection ability of PIR sensors to drive doors open and close as it senses the presence of humans approaching and leaving the door respectively. It also incorporates a metal detector to check and deny access to people carrying metal and trying to access the door. This is done to boost the security of the system.

1.3 Aims and Objectives of the Study

The following are the aims and objectives of this study

i. To design a device that will automatically open a door by detecting the presence of a person approaching the door.
ii. To construct an automatic door control using a PIR sensor and metal detector security alert to detect the presence of humans approaching the door and grant access through the door.
iii. To incorporate the microcontroller, servo-motor, PIR sensor, and metal detector and program them to function as desired.

1.4 Significance of the Study

The microcontroller-based automatic door system is one in which the sensor sends a signal to the microcontroller which checks if the person within the sensor range is with a metal and sends a signal to the servomotor which then swings to open the door. The sensor can be mounted above the automatic door is built on top of the frame or the sides of the frame of the door. Automation, as defined by the automation federation is "the creation and application of technology to monitor and control the production and delivery of products and services". Automatic doors have many useful purposes. They are helpful for people who are handicapped to access doorways without help. Also, people carrying things on both hands can access the doorways without manual effort on the door. This is why they are found in many locations like airports, hotels, supermarkets, banks, and many types of large buildings. The automation indoors is generally reserved for two purposes; Accommodating high flow of pedestrian traffic and providing accessibility for people with disabilities [2]. Automatic doors provide security especially when incorporated with security devices like metal detectors or authorization mechanisms like face recognition, biometric recognition, voice recognition, password-based systems, and smartcard systems. Automatic door technology can also be applied in gates where one does not need to come down from his/her car to open the gate. This system eliminates the cost of employing a gateman.

1.5 Scope of Study

This project work covers the use of PIR sensors for human sensing and opening and closing of doors. It also incorporates the use of a metal detector as a security check and the interfacing of the different components with a PIC family of microcontrollers to work cohesively.

2. Literature Review

2.1 Theoretical Framework

The motion-based automatic door opener is designed using a PIR sensor and a PIC16F877A microcontroller. The PIR sensor is a pyroelectric device that generates electric charges when exposed to infrared energy. The changes in the amount of infrared energy striking the element changes the voltage generated which is measured by the onboard amplifier in the sensor. This amplifier then trips the output to indicate motion. As motion is detected by the sensor, a message is sent to the microcontroller. The microcontroller waits until it receives a message from the metal detector indicating that no metal is detected before it sends a message to the servo motor which moves through 180 degrees to open the door.

2.2 Conceptual Framework

Different techniques can be designed to enable a user to communicate with the door system automatically such as face recognition, voice recognition, iris recognition, password-based recognition, smart card, and motion-based recognition. In this work, a passive infrared sensor is used for motion detection in the design and construction of a motion-based automatic door with a metal detector using the concept of infrared energy emitted by a body which is detected by the sensor. The concept of electromagnetic induction is also applied in the design of the metal detector. The servo motor also operates by the concept of electromagnetism. All these components of the circuit communicate with each other and are controlled by a PIC16F877A microcontroller. The microcontroller analyses the input from the PIR sensor and metal detector and gives an output to the servomotor which rotates to indicate door opening and door closing. AnLCD screen is used as an output device to display the door status (Door Opened or Door Closed) appropriately. When the input from the metal detector is high, indicating the presence of a metal approaching the door; the microcontroller sends a signal to a buzzer for security alert. The interaction between the components and the microcontroller is depicted in the block diagram.

2.2.1 Development of block diagram

The Block Diagram of the Automatic Door Opener is shown in Fig. 1

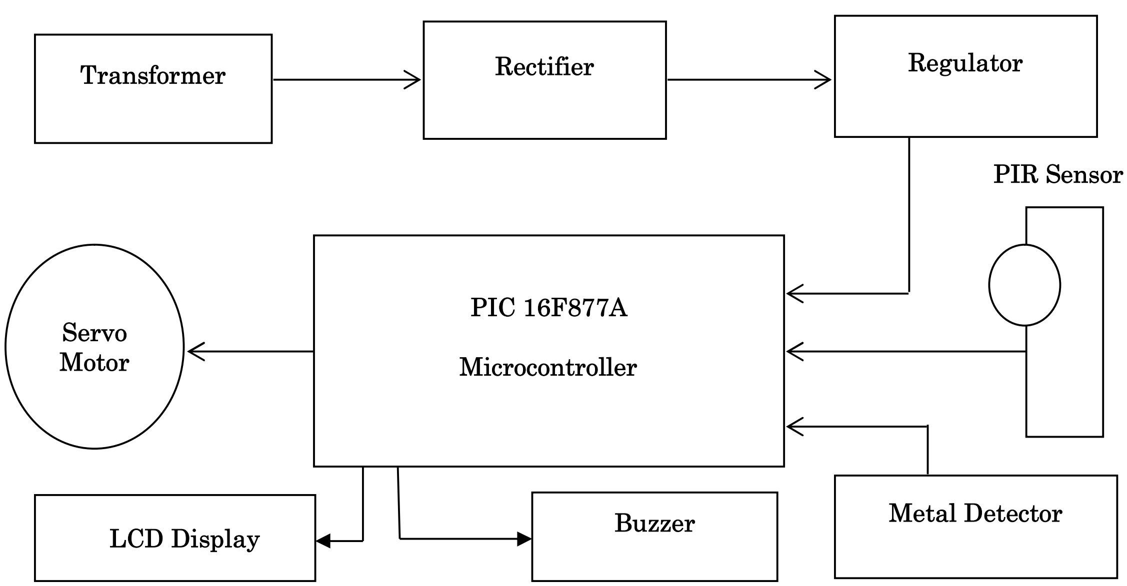

Fig. 1. *Block Diagram of the motion Automatic Door Opener*

2.3 Review of Related Empirical Studies

Researchers in the past have developed systems to automatically open and close doors, motion detection devices, and metal detectors using different methods and electronic devices to achieve their aim.
In 2014, Sravani *et al.*[11] designed and constructed a motion detection device using a passive infrared sensor. The device was designed to detect motion within the sensor range around a door and gives a signal to an AT89S51 microcontroller which triggers an alarm with the help of a buzzer. The microcontroller also sends a signal to a computer through a serial communication port to display the message "motion detected" on a computer screen.

In 2006, Shoewu and Baruwa[10] designed a microprocessor-based automatic gate that senses a vehicle approaching it and automatically opens and closes after a set time has elapsed. The system uses an optical sensor (Light Dependent Resistor) to provide an input signal to the system. Their system had a trigger circuit made up of a Schmitt-trigger quad two-input NAND gate which sends a message to the microprocessor when the body of a car obstructs the LDR increases its resistance to the dark resistance value and gives out a "high" input to the trigger circuitry. The high value causes the microprocessor to send a signal to the output port to activate a DC motor to control the gate opening or closing.

In 2014, Hnin *et al.*, [6] designed a microcontroller-based automatic railway gate control system to close and open gates at level crossing between railway and highway to prevent rail accidents at points of intersection between railways and highways. Their system makes use of a PIC16F877A microcontroller which receives input signals from sensors and sends information to the gate motor driver for opening and closing the gate. The input to the microcontroller was an infrared sensor fixed at some distance before and after the gate. As the train passes the first sensor, the microcontroller sends a signal to close the gate against road users and the gate opens when the train crosses the second sensor. The system also incorporates LCD, alarm, and indication light circuits to improve the efficiency of the system.

In 2016, Gowsalya *et al.*, [15] designed and constructed an automatic door-opening system, which is capable of opening and closing the door automatically using a PIR sensor. The hardware and software requirements for this project include an 8051 series microcontroller, transformer, PIR sensor, Motor Driver IC, Motor with sliding door, diodes, resistors, capacitors, crystal and transistors, Keil compiler as well as a C programming language. The sliding door was linked together with a DC motor shaft through a belt drive which takes a maximum of 600mA to run the motor. As the motor rotates, it converts rotational to linear motion and generates a signal in the form of two identical square wave signals which are first shifted by 90^{0}.

In 2016, Huthaifa *et al.*, [7] developed a system for the application of the PIC16F877A microcontroller. The research effort examined three sensor types, their data, and how to integrate them with a single microcontroller to accomplish simple tasks – dimming a light, sounding an alarm, and showing a temperature rise. Three sensor types were used in this effort. First, an ultrasonic sensor was used to measure the distance from an object. A temperature sensor was used for monitoring temperature change from a human touch. An LDR sensor was used to detect different levels of light in a room. The goal of their work was to make a smart device that could be used to solve simple problems.

In 2016, Win and Myo [13] designed a door operator for an automatic sliding door. The system operated by opening and closing the door automatically. The automatic sliding door had flat panels that slid horizontally and linearly. It consists of a motor, a controller, a power supply, a pulley system, and a battery. The controller module provided the interface with the drive motor and pulley. The motor was a permanent magnet DC motor which has the advantage of small size provides high torque at low speeds and rotates forward or backward to achieve the required door movement. Input to the sliding door systems were sensors that transmit information to the motor via a PIC16F877 microcontroller.

In 2010, Obiazi *et al.*, [8] designed and implemented a metal detector using a colpitts oscillator with toroidal coil. It consists of an RF transistor Colpitts oscillator and a toroidal coil as inductor which acts as a transducer that converts magnetic variations to voltage level changes through a direct feedback mechanism. The system had a tank circuit set such that the feedback voltage was enough to maintain oscillation when there were magnetic variations due to the presence of a metal. The initial set position was distorted automatically cutting off oscillation and also the transistor due to the biasing employed.

2.4 Summary of Related Literature

It has been reviewed that the motion-based automatic door opener with a metal detector can be designed, constructed, and assembled with a servo motor, PIR sensor for sensitivity of human motion as well as a metal detector. The PIC16F877A microcontroller was chosen for the work due to its low cost, easy programming, reliability, and availability in the market.

3. Circuit Analysis and Design

3.1 Circuit Analysis

3.1.1 Analysis of the Power Supply Unit

All components used for the achievement of this project work require a very stable source of energy free from too much fluctuation. Rectified DC voltage is used because if the work is designed for battery, it will require constant charging and can be burdensome. A full wave rectification of AC is used to provide a stable DC voltage to power the components; the microcontroller, the PIR sensor, the servo motor, and the metal detector.

A center tap transformer is used and requires two diodes. The diode converts bidirectional input into unidirectional outputs. When a positive voltage is applied to the base of the diode, the diode is forward-biased and allows maximum current through it. When the negative voltage cycle flows to the diode, it is reverse-biased, and no current flows to the circuit. The secondary transformer has the same number of turns between the center tap at its output coil. The transformer and the diodes are used for phase reversal in this work. Fig 2 shows the circuit diagram of the Power Supply Unit.

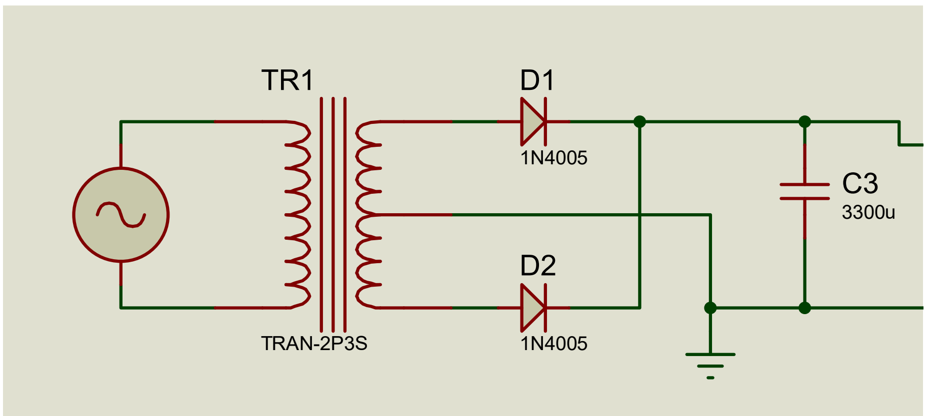

Fig. 2. *Circuit Diagram of Power Supply Unit*

The phase reversal is done such that when a positive cycle of voltage is applied, D1 is forward biased and pumps current to the load but diode D2 is reverse biased and as such does not allow current through it. When a negative cycle of voltage is applied, D1 becomes open-circuited and D2 is forward-biased, and as such a full wave rectification is achieved. The output of this stage contains a lot of ripple and a capacitor is used to store charges in the output of the transformer and discharges through the load. There exists some amount of ripple which is tolerated to some extent. The time constant of the circuit is made much greater than the period of the waveform i.e. $R_c >> T$ Where T is the period of the waveform and Rc is the time constant. The capacitor is chosen to have a value much greater than I/R i.e. C >> I/RA12V DC gotten from the transformer which is regulated to obtain 5V. An estimated load current of 1A from the circuit and a ripple of 2% is tolerated.

$$Ripple\ Factor\ = \frac{RMS\ of\ Voltage}{Average\ DC\ Voltage\ drop} X100 \tag{1}$$

$$RMS\ of\ ripple\ voltage\ = \frac{Vpp}{3} \tag{2}$$

Average DC Voltage = 12V and the factor is $\frac{2}{100}$.The peak-to-peak voltage Vpp can be expressed in terms of the average DC voltage is expressed as

$$V_{pp} = \frac{V_{avg}}{3X12}$$

$$V_{pp} = \frac{2X\sqrt{3}X12}{100} = 0.42V$$

Based on the assumption made earlier, we have a drop of 0.42V from the peak voltage during discharge which satisfies that RC>>T. The capacitor voltage becomes

$$V_c = V_p \left[e^{\frac{-\tau}{RC}} \right] \tag{3}$$

$$V_c = V_p \left[1 - \frac{T}{RC} - \left(\frac{T}{RC} \right)^2 . \frac{1}{2!} - \left(\frac{T}{RC} \right)^3 . \frac{1}{3!} ... \right] \tag{4}$$

Neglecting the higher terms because $\frac{T}{RC}$ is far less than 1. Then $V_c = V_p \left[1 - \frac{T}{RC} \right]$ which is linearthe fact that 1>> $\frac{T}{RC}$ shows that $V_c = V_p$, which is approximately constant and it is what we need.

The peak-to-peak voltage becomes

$$V_{pp} = V_{dc} . \frac{T}{RC} \tag{5}$$

Then equating Eqn. (3) and (5), we obtain

$$0.42 = \frac{12 X 20 X 10^{-3}}{\frac{VC}{I}}$$

Where $T = \frac{1}{F} = \frac{1}{50} = 20 m\sec$

i.e., $0.42 X 12 C = 12 X 20 X 10^{-3}$

$$C = \frac{20 X 10^{-3} X 12}{0.42 X 12}$$

$$C = 47.62 X 10^{-3} F$$

$$C = 47620 \mu F$$

3.1.2 Diode Specifications

During the first positive half cycle, D1 is forward biased and second diode D2 is reversed biased which is subject to a reverse bias voltage of 24V. So we choose a diode of 1N4004 with a large peak inverse voltage which goes for D1when D2 is reverse biased.

3.1.3 Regulation of Voltage

A 5V voltage regulator LM7805 is used to obtain a stable voltage for the components.

3.1.4 Power Dissipation of the Regulator

The regulator dissipates some amount of energy in the form of heat to the environment. This energy may become a problem if the margin of regulation is high and no method of compensation is made I_c to dissipate the energy to the environment or help maintain a stable temperature during operation. The energy is calculated as shown below

$$P = IV$$

$$P = I \left[V_i - V_o \right]$$

Where V_i = input voltage, V_o = output voltage, I =1A, i.e.,

$$P = 1 \left[12 - 5 \right]$$

$$P = 7 watt$$

This value is very large and a heat sink will be used to dissipate the heat. A power indicator LED with a red color was used with a rating of 2.8V drop.

$$R = \frac{5 - 2.8}{20 mA} = 110 \Omega$$

3.1.5 Analysis of the PIR Sensor

The PIR sensor is an electronic device that detects senses and measures IR light radiated from objects in its area of designed coverage or detection range. All bodies emit black body radiation as a form of energy. This radiation is not visible to human eyes but can be detected by infrared sensors. This principle is applied here in the design. If a person approaches the door, the temperature around the coverage of the PIR sensor differs from the ambient temperature of the environment before the person approaches the coverage area. By slight temperature difference, the PIR sensor emits or induces a voltage which is detected by the microcontroller and then accomplishes its decision.

The PIR sensor requires a stable 4.5V- 20V power supply. It has a maximum range of 9m and a view angle of 110^0. It displays an output of zero (0) when motion is not detected and 3V or 5V when motion is detected. The PIR sensor has three pins namely; the output pin, the power pin, and the ground.

3.1.6 Analysis of the Servo Motor

The application of a servo motor is usually for locking and unlocking as well as swinging the door. This motor works on the principle of electromagnetic induction but in a more controlled fashion. A servo motor has an arm and three (3) wires for connecting V_{cc}, ground, and a control signal called a pulse. The position of the arm depends on the pulse width of the rectangular wave sent to the control signal as shown in Fig. 3.

The arm can swing from 0^0 to 180^0which makes it a very good device for our application. The pulse that determines the position of the arm of the servo motor is not dependent on the duty cycle of the PWM but rather on the length of time or inverse of the frequency at which the pulse or signal is applied.

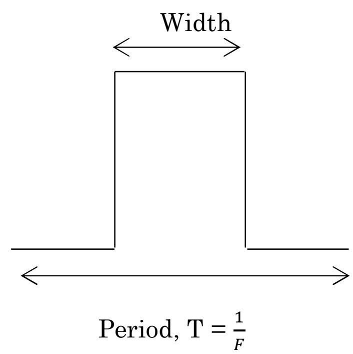

Fig. 3. *Pulse Width Modulation for Servo Motor Control*

For demonstration, we have decided to use the Hitec HS422 servo motor which has the following specifications.

Power supply = 5V,

The angle of rotation = $0^0 - 180^0$ of range,

Stall torque of 3.3kgcm at 4.8.

The frequency supply of pulse 50Hz which gives a period of T $\frac{1}{f} = \frac{1}{50}$ = 20msec.

We use the time or period to move the arm to the positions we want it to go. The Servo Motor Trajectory is shown in Fig. 4.

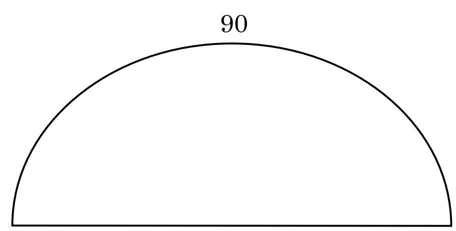

Fig. 4. *Servo motor Trajectory*

If a signal is applied to the motor and it lasts for 1.5msec, it moves the arm to 90^0position and the motor stays there and such, if a signal is applied to the motor that lasts for 0.6msec the arm moves to 0^0 of the angle.

This is possible because of the gears and potentiometer with some electronics packaged together with the motor which helps to remember its position and hence goes to wherever it wants.

The block diagram of the internal circuitry of a servo motor is shown in Fig. 5

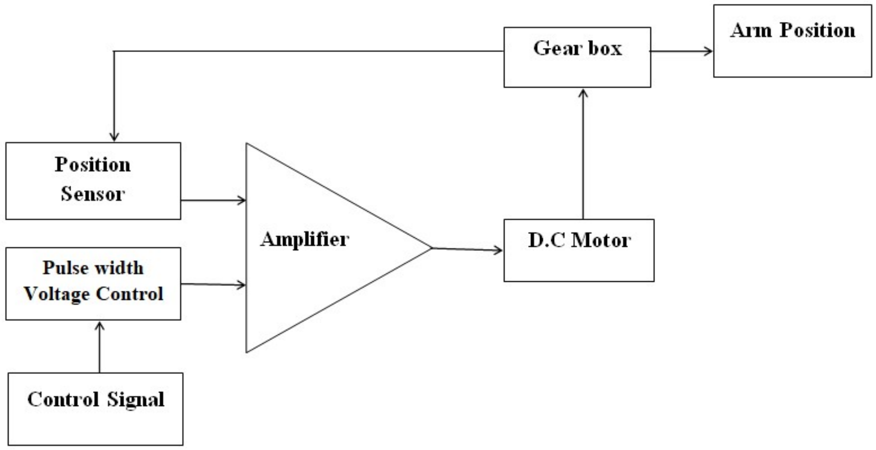

Fig. 5. *Block Diagram of a Servomotor*

When the DC motor is rotating, it lowers the gear which causes the arm to turn the potentiometer. This gives some feedback on how much the arm has turned. The potentiometer provides feedback on how much the gear has turned and the signal is applied at the control signal. The servo motor is capable of remembering its position via the potentiometer as the desired position is fed into the servomotor circuit and is compared with the actual position. The error is used to move the motor further or backward depending on the error we have calculated based on the position of the angle. The servomotor rotates in terms of time at about 600msec for close position and 19400msec for open position. An MG996R servomotor as shown in Fig. 6 is used for this work which rotates approximately 120^o(60^o in each direction) with an operating voltage between 6V and 7.2V and an operating speed of $0.17s/60^o$.

Fig. 6: *MG996R Servomotor*

3.1.7Analysis of the Metal Detector

The metal detector consists of a TDA0161 proximity detector IC which detects metal objects by detecting small changes in the high-frequency eddy current losses in an inductor coil. The inductor is a 30 AWG copper wire wound into a coil of 140 turns using a 5cm diameter reference with a 1cm thickness.

The parallel combination of the inductor and capacitor (Tank circuit) is the main metal detector. When the Inductor Capacitor (LC) circuit detects a resonating frequency from any metal near it, an electric field will be created which will lead to an induced current in the coil and changes in the signal flow through the coil. The TDA0161 is first tuned using a potentiometer to achieve uniform frequency with the tank circuit. The presence of a metal around the inductor coil increases its resistance above the tuned resistance of the potentiometer and due to the difference in frequency, the TDA0161 gives an output. The output of the proximity sensor will be about10mA when a metal is close to the inductor coil and less than 1mA when there is no metal close to the coil. There is a filtering capacitor connected between pins 5 and 7 of the TDA0161 IC. The output pin, (pin 6) of the IC is used to drive the buzzer through the transistor acting in two modes.

1. Cut off mode when there is no metal target.
2. Saturation mode when a metal is detected.

The large signal model of the transistor is shown in Fig. 7.

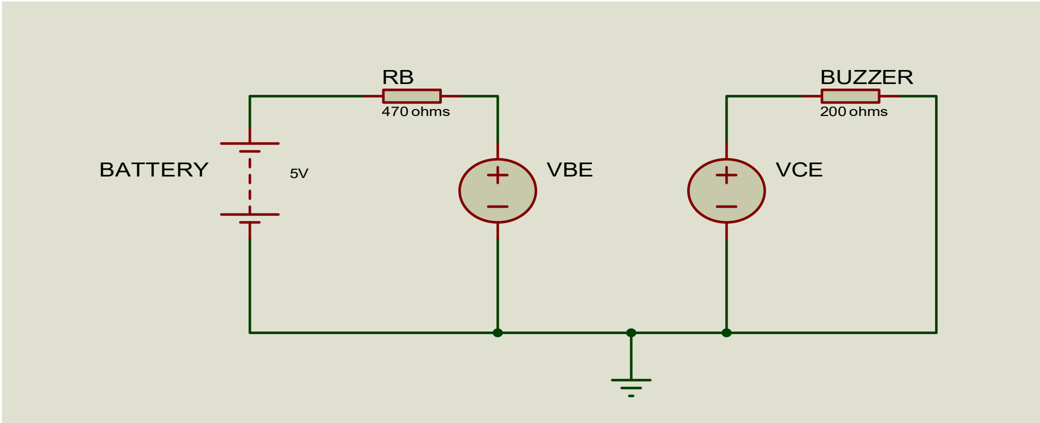

Fig. 7. *Large Signal Model of the Transistor*

From data sheet ß=100, V_{BE} (sat) = 0.85V, V_{CE}(sat) = 0.2VCut off mode of transistor calculation:

I_B= 0mA, I_C=0mA.

Saturation mode calculation

$V_{BE\,(sat)}$ = 0.85V and $V_{CE\,(sat)}$ = 0.2V, R_b = 470Ω.

$I_B = \frac{+5-Vb\ \ (sat)}{Rb}$; $I_B = \frac{+5-0.85}{470}$ = 8.83mA

Buzzer impedance = $\frac{5V}{20mA}$ = 200Ω.

$I_C = \frac{+5-0.2}{200}$ = 24mA.

Winding inductance (L) calculation:

Diameter, d=5cm=0.05m, l=1cm=0.01m, N=140 turns and μ = 4π x 10^{-7}.

$$L = \frac{N^2 A\mu}{l} = \frac{\mu N^2 \pi d^2}{4l}$$

$$L = \frac{4\pi \text{ x } 10^{-7} \text{x } 140^2 \text{x } \pi \text{ x } 0.05^2}{0.01 \text{ x } 4} = 4.84\text{mH} \approx 5\text{mH}.$$

Operating frequency of Detector

Frequency f = $\frac{1}{2\pi\sqrt{lC}}$,

Where C = 47nF and L = 5mH.

Hence, f = $\frac{1}{2\pi \text{ x } \sqrt{(5\text{x } 10^{-3}\text{x } 47\text{x } \quad {}^{-9})}} \approx$ 10kHz.

Fig. 8 shows the circuit diagram of the metal detector.

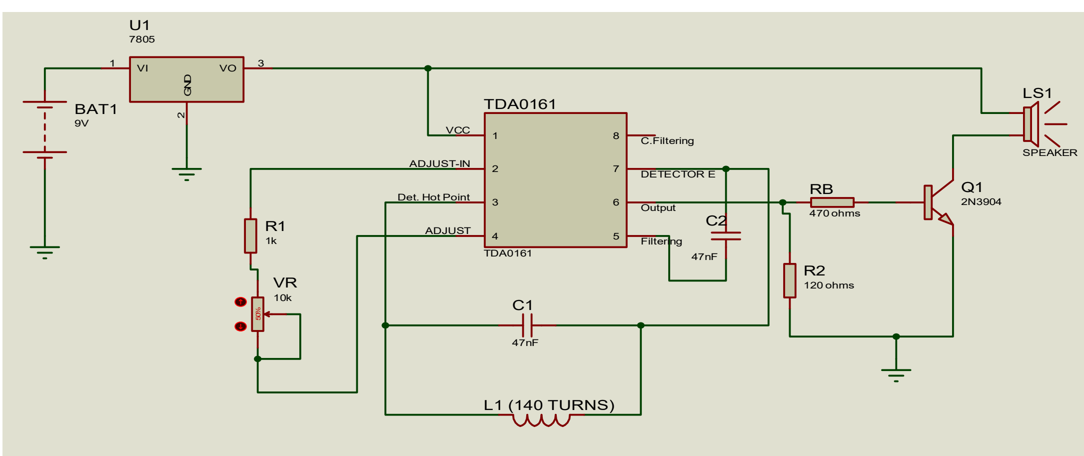

Fig. 8. *Circuit Diagram of the Metal Detector*

3.1.8 Liquid Crystal Display (LCD)

The LCD is an output device used to present information in text form. It is controlled to display information or the status of a device by being interfaced with a microcontroller. LCDs work based on the principle of blocking light. They are a combination of two states of matter (solid and liquid). It uses a liquid crystal composed of several layers which include two polarized panel filters and electrodes to produce visible images or text. When electric current is applied to the liquid crystal molecule, the molecule tends to untwist. This causes the angle of light that is passing through the molecule of the polarized glass and causes a change in the angle of the polarized filter. As a result, light is allowed to pass the polarized glass through a particular area of the LCD and that area becomes dark compared to the other. An electrode plane made of indium-tin oxide is kept on top of the polarized glass with a polarizing film added tothe bottom of the device. When there is no current, the light passing through the front of the LCD will be reflected by a mirror and bounced back. As the electrode is connected to a battery, the current from it will cause the liquid crystals between the common plane electrode and the rectangular electrode to untwist. Thus, the light is blocked from passing through and the rectangular area appears blank.

A 16 X 2 (HD44780) LCD module is used for this project (i.e. it consists of 2 lines which can display 16 characters per line.). This LCD can be operated in either a 4-bit or 8-bit mode. It has two registers. The command register and the data register. The command register stores the command instructions given to the LCD. A command is an instruction given to the LCD to do a predefined task like initialization, clearing the screen, setting the cursor position, and controlling the display. The data register stores the data to be displayed on the LCD. It consists of 3 selection lines 8 data lines and by connecting these lines, messages can be displayed on LCD screen.

The EN (Enable) control line is used to send data to the LCD. A high-to-low transition at this pin enables the module.

The RS (Register Select) control line specifies if the data is to be treated as a command instruction or to be displayed. When RS is set 'high' characters are displayed on screen.

The RW (Read/Write) control line is kept 'low' to allow information to be written to the LCD. When RW is 'high', the program would be effectively reading the LCD.

The data bus consists of 4 or 8 lines depending on the mode of operation by the user. The lines of the 8-bit data bus are numbered DB0, DB1, DB2, DB3, DB4, DB5, DB6, and DB7 as shown in Fig. 9.

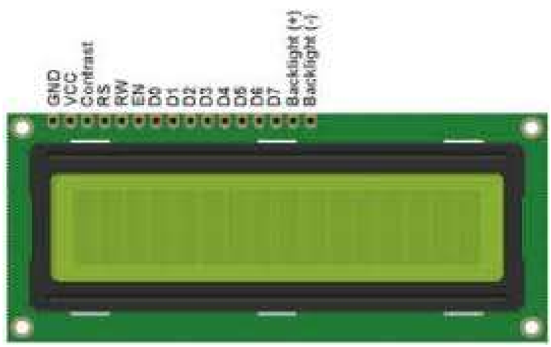

Fig. 9. *A 16 X 2 LCD Display*

3.2 Overview of Microcontroller

The PIC16F877A microcontroller is one of the most renowned microcontrollers and is applied in a large number of devices ranging from remote sensors, security and safety devices, home automation, and many industrial instruments. It has a total number of 40 pins and there are 33 pins for input and output. It consists of two 8-bit and one 16-bit counters.

One of the main advantages of PIC16F877A is that it can be write–erased as many times as possible because it uses FLASH memory technology. It is very convenient to use and the coding of the controller is easier. An EEPROM is also featured in it which makes it possible to store some information permanently like transmitter codes and receiver frequencies. The cost of this microcontroller is low and its handling is also easy. The PIC16F877A microcontroller and its pin configuration are shown in Fig. 10 and Fig. 11 respectively.

Fig. 10. *PIC16F87A Microcontroller*

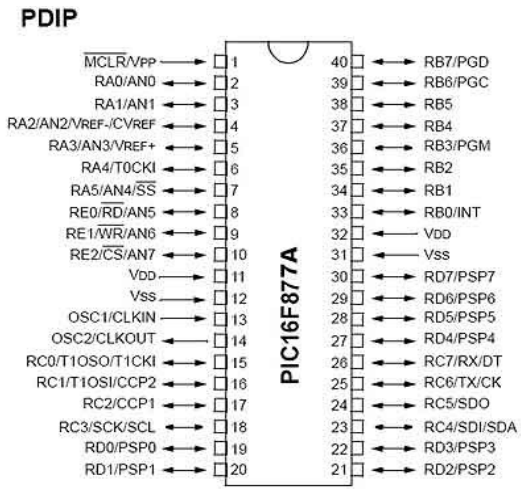

Fig. 11. *Pin Configuration of PIC16F877A Microcontroller*

3.2.1 Pin Description of PIC16F877

Pin 1(MCLR): This first pin is the master clear pin of the IC. It resets the microcontroller and is active low meaning that it should constantly be given a voltage of 5V and if 0V is given, the microcontroller is reset. Resetting the microcontroller will bring it back to the first line of the program burned into the IC. A push button and a resistor are usually connected to the pin as shown in Fig. 12. The pin is already being supplied by constant 5V. When the IC is to be reset, the button is pushed which will bring the MCLR pin to 0 potential thereby resetting the controller

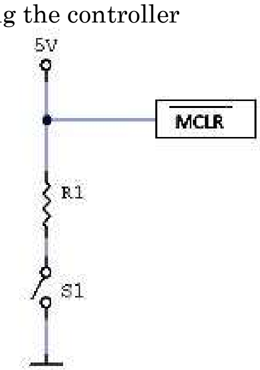

Fig. 12. *Master Clear (MCLR) Connection of Microcontroller*

Pin2 (RA0/AN0): PORTA consists of 6 pins (pin 2 to pin 7)which are all bidirectional input/output pins. Pin 2 is the first pin of this port. This pin can also be used as an analog pin. It is a built-in analog-to-digital converter.

Pin 3 (RA1/AN1): This can be the analog input 1.

Pin 4 (RA2/AN2/Vref-): This can also act as analog input 3 or negative analog reference voltage can be given to it.

Pin 5 (RA3/AN3/Vref+): It can act as analog input 3 or analog positive reference voltage.

Pin 6 (RA0/T0CK1): To timer0this pin can act as the clock input pin. The type of output is an open drain.

Pin 7 (RA5/SS/AN4): This can be the analog input 4. There is a synchronous serial port in the controller and this pin can be used as the slave select for that port.

Pin 8 (RE0/RD/AN5): PORT E starts from pin 8 to pin 10 and is also a bidirectional input/output port. It can be the analog input 5 or for parallel slave port it can act as a 'read control' pin which will be active low.

Pin 9 (RE1/WR/AN6): This pin can be the analog input 6 and can act as the 'write control' for the parallel slave port which will be active low.

Pin 10 (RE2/CS/A7): This pin can be the analog input 7, and can act as the 'control select' for the parallel slave port which will also be active low just like read and write control pins.

Pin 11 and32 (VDD): These two pins are the positive supply for the input/output and logic pins. Both of them should be connected to 5V.

Pin 12 and 31 (VSS): These pins are the ground reference pins for input/output and logic pins. They are normally connected to 0 potential.

Pin 13 (OSC1/CLKIN): This is the oscillator input or the external clock input pin.

Pin 14 (OSC2/CLKOUT): This is the oscillator output pin. The crystal resonator is connected between pin 13 and 14 to provide external clock to the microcontroller. $\frac{1}{4}$ of the frequency of OSC1 is outputted by OSC2 in case of RC mode. This indicates the instruction cycle rate. Fig. 13 shows the crystal oscillator connection to the microcontroller.

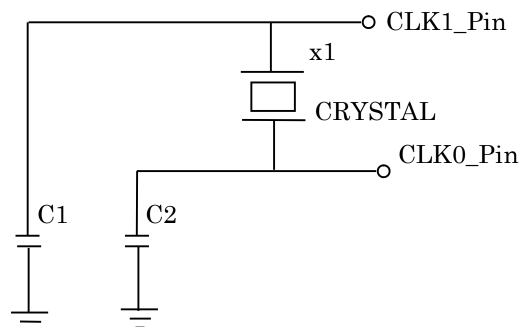

Fig. 13. *Crystal Oscillator Connection between Pin 13 and 14*

Pin 15 (RC0/T1OCO/T1CK1): PORTC consists of 8 pins. It is also a bidirectional input/output port. Of them, pin 15 is the first. It can be the clock input of timer 1 or the oscillator output of timer 2.

Pin 16 (RC1/T1OSI/CCP2): It can be the capture 1 input of timer 1 or the capture 2 input/compare 2 output/ PWM 2 output.

Pin 17 (RC2/CCP1): It can be the capture 1 input/Compare 1output/ PWM 1 output.

Pin 18 (RC3/SCK/SCL): It can be the output for SP1 or 12C modes and can be data input/output for a synchronous serial clock.

Pin 19,20,21,22,27,28,29,30: All of these pins belong to PORT D which is again a bidirectional input/output port. When the microcontroller bus is to be interfaced, it can act as the parallel slave port.

Pin 23 (RC4/SD1/SDA): It can be the SP1 data pin or in 12C mode, it can be the data input/output pin.
Pin 24 (RC5/SDO): It can be the data output of SP1 in the SP1 mode.

Pin 25 (RC6/TX/DT): It can be the synchronous clock or USART asynchronous transmit pin.

Pin 26 (RC7/TX/DT): It can be the synchronous data pin or the USART receive pin.

Pin 33-40 (PORT B): All these pins belong to PORT B. The output of which RB0 can be used as the external interrupt pin and RB6 and RB7 can be used as in-circuit debugger pins.

3.2.2 Crystal Oscillator

An 8MHz Quartz crystal oscillator is used in the microcontroller for providing clock signals. It is an electronic device that is used to generate periodically oscillating electronic signals. An electrical signal of precise frequency is generated by utilizing the vibrating crystal's mechanical resonance made of piezoelectric material. Quartz crystal oscillators are highly stable have a good quality factor are small in size and are very economical. Fig. 14 shows an 8MHz crystal oscillator with 20nF capacitors used to provide the clock signal.

Fig. 14: *An 8MHz Crystal Oscillator*

3.3 Flow Chart

The flow chart illustrates the sequence of execution of the program written to the controller from the micro C Pro environment. The flow chart is illustrated as shown in Fig. 12.

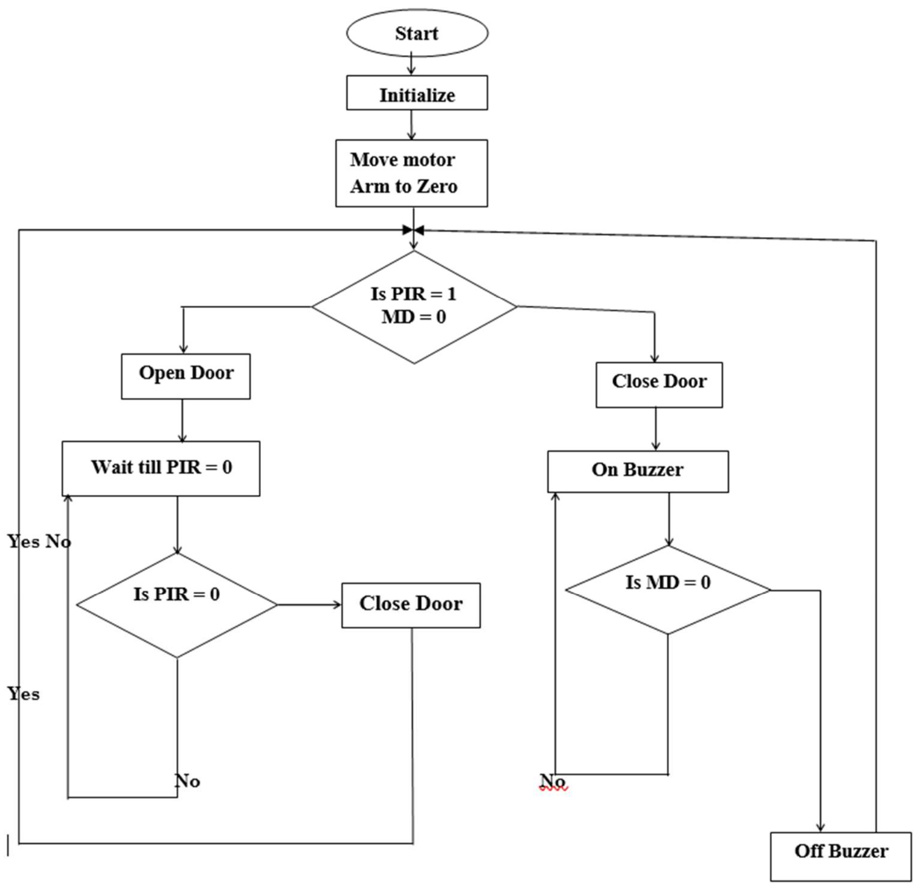

Fig. 15. *Flow Chart of the Automatic Door Opener*

3.4 Programming

The program is written on the micro C Pro for the PIC IDE environment of the 6.6 version. The program is in such a manner as illustrated in the flow chart. It initiates the required part and moves the servo motor from the position of 90^0 to 0^0 because the door is to swing between $0^0$to 180^0.

When the port carrying the PIR and the metal detector circuit are both high, then the door will not open and it sounds an alarm indicating that it has sensed a metal but if the PIR is high and the metal detector is low. It implies that no metal is detected so it swings the servo motor arm to $180^0$and waits till the PIR port is low before it swings back to 0^0 to close the door.

All these were done with the help of a microcontroller which calls for several functions into the infinite loop.

3.5 Simulation Model

The simulation model was done on a Proteus environment with all the components required except a metal detector in which a logic gate was used for a stable test to impress a voltage at the appropriate port. The simulation is done as shown in Fig.16 to 19.

When the PIR sensor and metal detector are 'low', the servo motor turns to an angle -90^o.i.e., the door is closed as shown in Fig. 16.

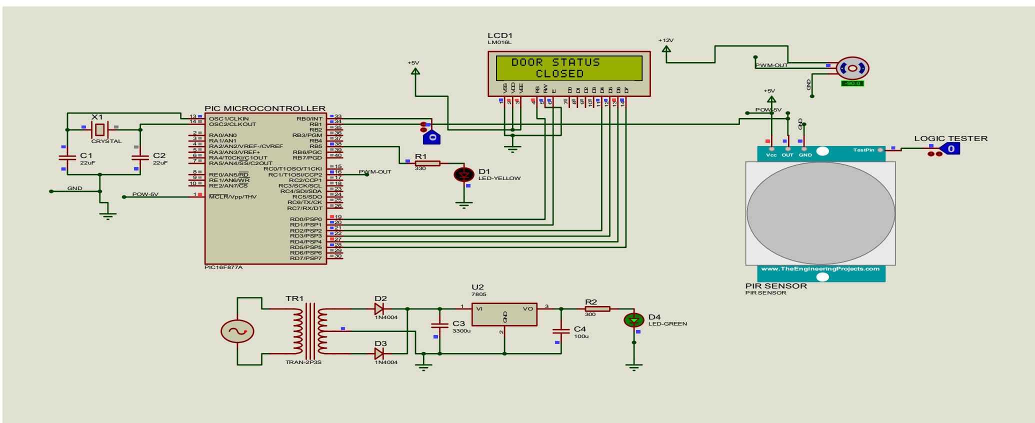

Fig. 16. *Simulation Model with PIR = 0 and Metal Detector = 0*

When the PIR sensor is 'high' and the metal detector is 'low**,** the servo motor swings to $+90^o$ and the door opens as shown in Fig. 17.

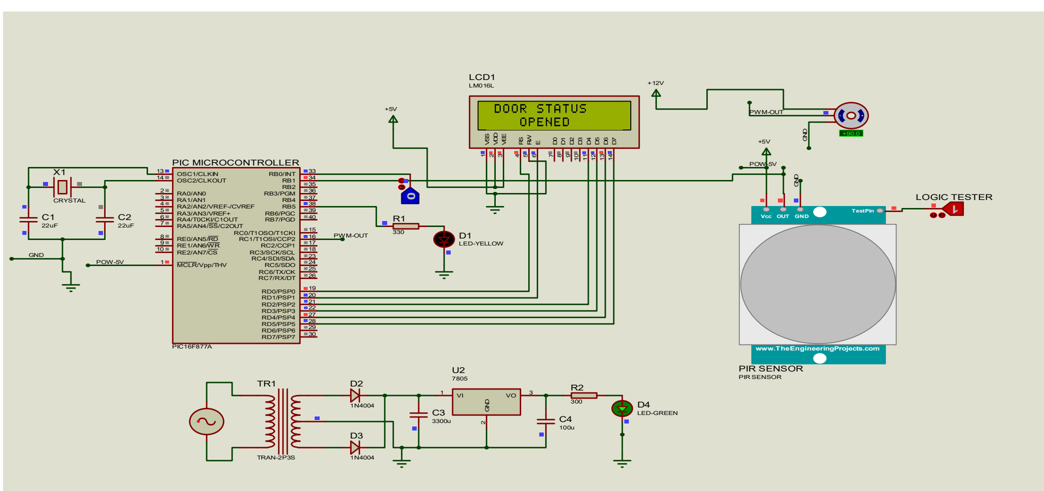

Fig. 17. *Simulation Model with PIR = 1 and Metal Detector = 0*

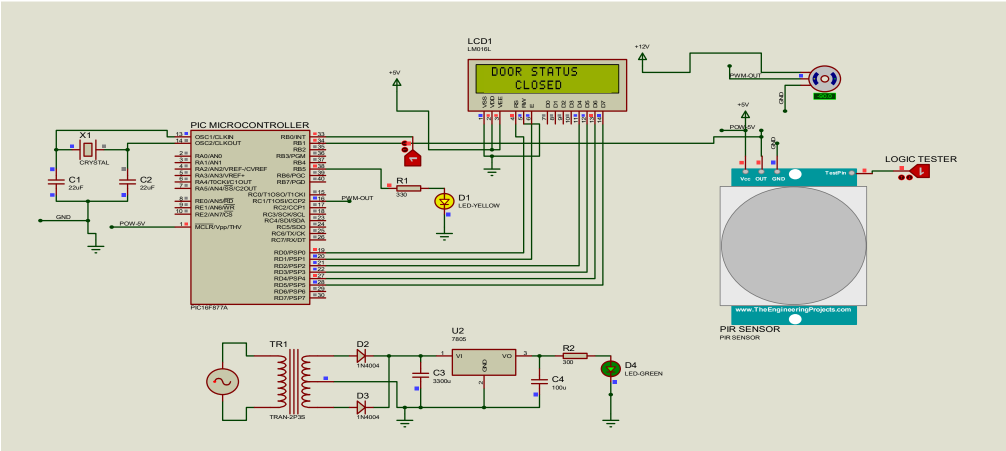

Fig. 18. *Simulation Model with PIR =1 and Metal Detector = 1*

Fig. 18 shows that when PIR sensor and metal detector is 'high', the servo motor swings to -90º and closes the door.

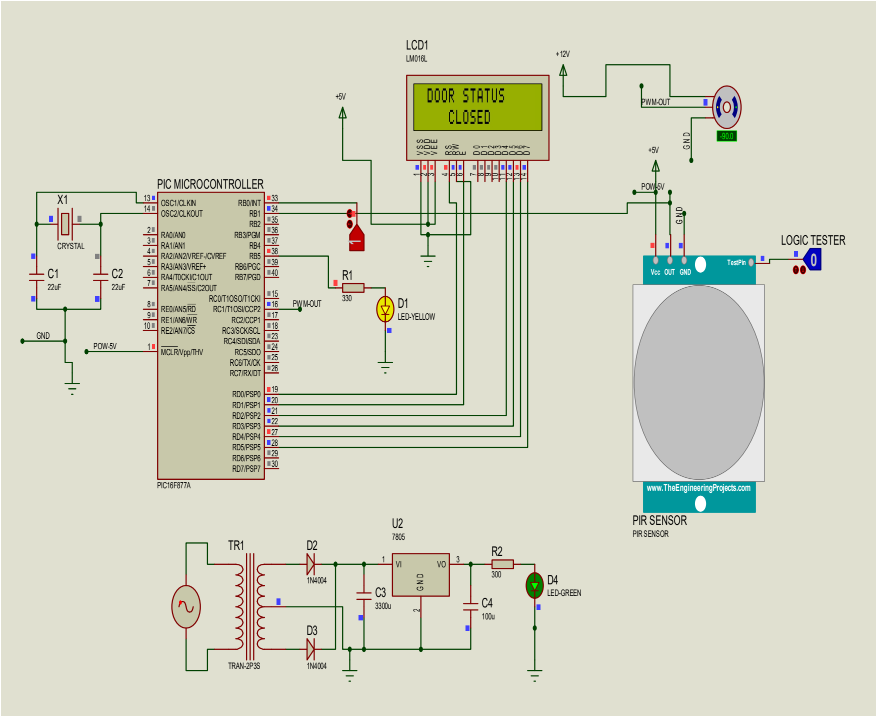

Fig. 19. *Simulation Model with PIR = 0 and Metal Detector = 1*

When the PIR sensor is 'low' and the metal detector is 'high', the servo motor turns to -90º and the door remains closed as shown in Fig. 19.

3.6 Circuit Diagram

The complete circuit diagram of the automatic door opener with a metal detector is shown in Fig. 20.

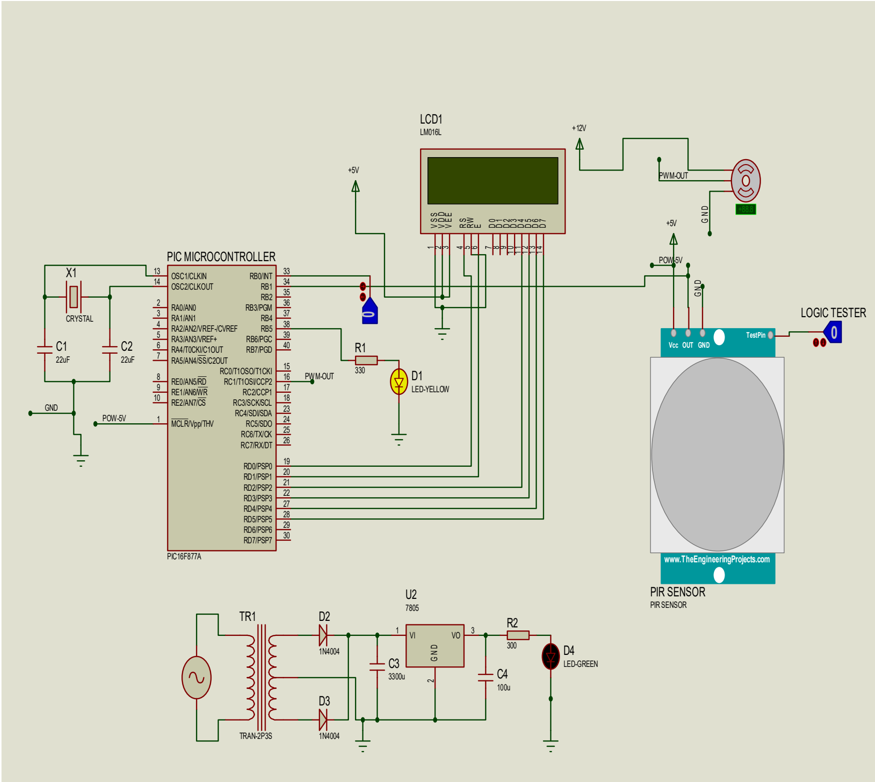

Fig. 20. *complete Circuit Diagram of Automatic Door Opener*

4. Construction, Testing, Results And Discussion

4.1 Construction

The construction of the work entails mounting and appropriately connecting all the selected components of the circuit as obtained from the analysis and design done. The circuit designed on the Proteus 8.4 environment was first implemented on a breadboard to confirm its workability before final implementation on the veroboard.

The program for the microcontroller was first burnt into the microcontroller using a PICKIT2 programmer. This was done by connecting the appropriate pins of the programmer to the corresponding pins on the microcontroller and importing the code (hex file) to be burnt into the microcontroller.

A breadboard was then used for the temporary implementation of the circuit. All the components that make up the circuit were placed on the breadboard and jumper wires were used to establish a connection between them. The work was then transferred to the Veroboard where permanent soldering was done after the workability of the circuit had been confirmed from the work on the breadboard.

An inductor wire metal detector was designed, constructed, and incorporated into the Automatic Door Opener circuit which works to send a message to the microcontroller to keep the door shut when a metal is detected within its range and also to turn on a buzzer for security alert.

4.2 Testing

This circuit was tested to confirm that the desired performance from the design was achieved. Continuity tests were run using a multimeter to confirm a proper connection between the different components of the circuit. Rectified DC voltage from the power supply was applied to power the circuit and was tested for a person within the PIR sensor range and without a metal. The circuit was also tested for a person within sensor range and with a metal close to the metal detector as shown in Fig. 21 and Fig. 22 respectively.

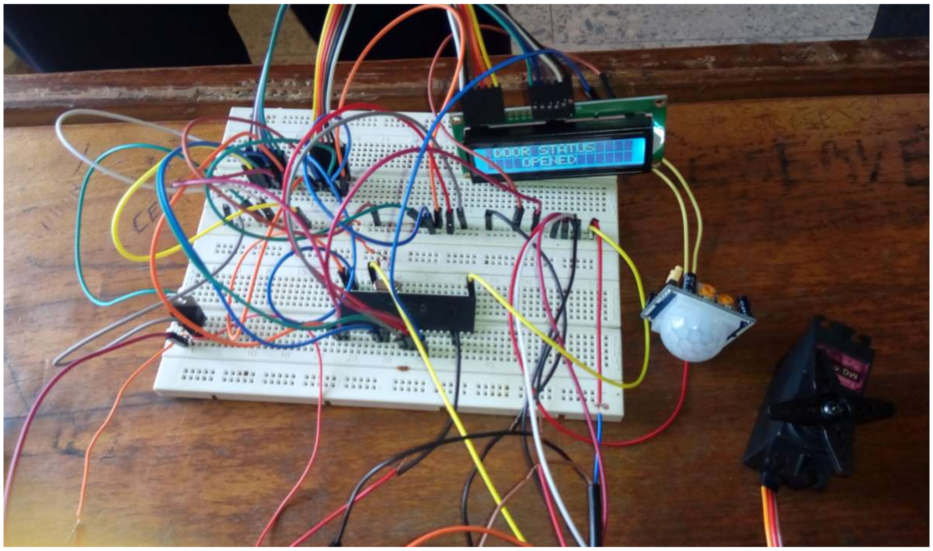

Fig. 21. *Testing on Breadboard with PIR 'high' and Metal Detector 'low'*

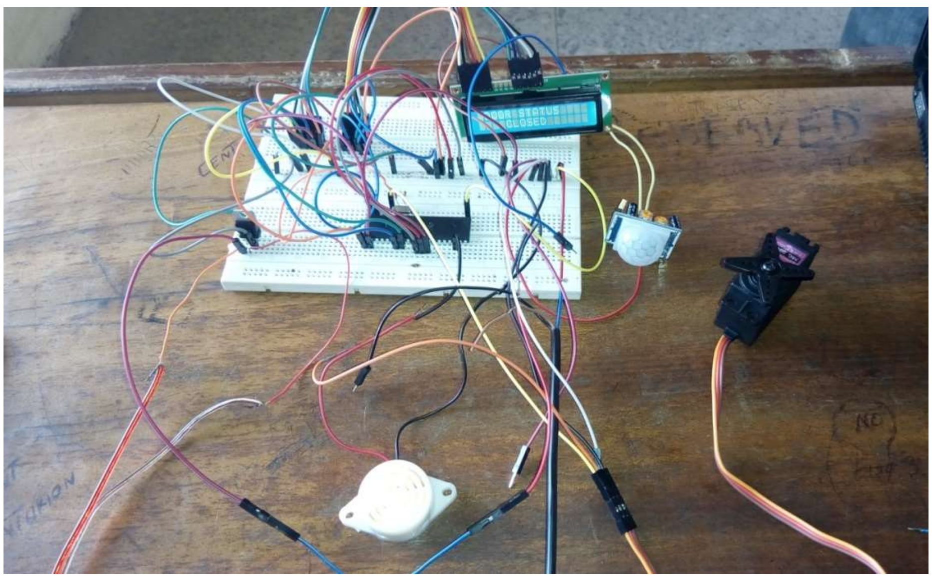

Fig. 22. *Testing on Breadboard with PIR 'high' and Metal Detector 'high'*

4.3 Results

The result shows that the circuit works as expected for the door opens only when a person without a metal is around the PIR sensor range and the LCD outputs the door status 'Door Opened'. For other conditions when a person is within sensor range and with a metal, the LCD outputs the door status 'Door Closed'. The door status remains closed until when the PIR sensor is 'high' and the Metal Detector 'low'. The PIR sensor detects human presence within a range of 3m-9m and the metal detector constructed detects metals within a range of 5cm.

4.4 Discussion

The testing done and the results achieved show that the actual construction and performance of the motion-based automatic door opener meet the expected working of the designed circuit and the aims and objectives of the proposed work.
The challenges encountered during this work include

1. It was difficult getting some of the components required for the work locally which were then ordered online and took some time to arrive
2. Some components delivered from the online sources were not the exact specifications requested and resulted in a few anomalies during the testing of the work.

3. The servomotor which drives the door and metal detector draws a lot of current from the power supply so a transformer with a higher current rating was then used in the construction of the power supply unit.

5. Conclusion and Recommendation

5.1 Conclusion

After the completion of this work, the initial aims and objectives set out to be achieved as stated in the introductory part of this report have been successfully attained.

1. A device that automatically opens a door by detecting the presence of a person approaching the door was successfully designed.
2. An automatic door control using a PIR sensor and metal detector security alert to detect the presence of humans approaching the door and granting access through the door was achieved.
3. A microcontroller, servo-motor, PIR sensor, and metal detector were interfaced and programmed to function as desired.

This project work meets the requirement for application in areas where they are needed

5.2 Recommendations.

The following are recommended for further improvement of this work;

4. The system can be upgraded to prevent false opening of the door such that it opens only to persons intending to access the door.

More sensitive sensors should be used which will differentiate between humans and animals as PIR sensors can sense body heat from both humans and animals.

APPENDICES

1. Program for PIC Microcontroller Using Micro C

```
void open_door()  // move servo motor to 180 degree
        {
        unsigned int i;
for(i=0; i<50; i++)
        PORTC.F1=1;
delay_us(2200);
        PORTC.F1=0;
Delay_us(17800);
        }
        void close_door() // move servo motor to 0o degree
        {
        unsigned int i;
for(i=0; i<50; i++)
        PORTC.F1=1;
Delay_us(600);
        PORTC.F1=0;
delay_us(19400);
        }
sbit LCD_RS at RD0_bit;     // LCD initialization
sbit LCD_EN at RD1_bit;
sbit LCD_D4 at RD2_bit;
sbit LCD_D5 at RD3_bit;
sbit LCD_D6 at RD4_bit;
sbit LCD_D7 at RD5_bit;

sbitLCD_RS_Direction at TRISD0_bit;
sbitLCD_EN_Direction at TRISD1_bit;
sbit LCD_D4_Direction at TRISD2_bit;
sbit LCD_D5_Direction at TRISD3_bit;
sbit LCD_D6_Direction at TRISD4_bit;
sbit LCD_D7_Direction at TRISD5_bit;

void main() {
```

```
TRISB.RB5=0; // set portb5 as output pin
TRISB.RB1=1; // set portb1 as input pin
TRISB.RB0=1; // set portb1 as input pin
TRISC.RC1=0; // set portc1 as output pin
ADCON1=0XFF;
PORTB.RB5=0; // initialize portb5 with 0
close_door();    // close door
Lcd_Init();
PORTB=0X00;                       // Initialize LCD

Lcd_Cmd(_LCD_CLEAR);              // Clear display
Lcd_Cmd(_LCD_CURSOR_OFF);         // Cursor off
lcd_Out(1,2,"AUTO-DOOR WITH");    // print   AUTO DOOR WITH on the LCD screen
lcd_Out(2,2,"METAL DETECTOR");  // print   METAL DETECTOR onLCD the screen
delay_ms(1000);
Lcd_Cmd(_LCD_CLEAR);
lcd_Out(1,2,"DOOR STATUS"); // print   DOOR STATUS on the LCD screen
while(1)
 {

if(PORTB.B1==0 && PORTB.B0==0)   //check if human with metal is present
  {
    PORTB.RB5=1; // sound alarm
close_door();    // call function to close door
lcd_Out(2,5,"CLOSED");  // print CLOSED on the lcd screen
  }

if(PORTB.B1==0 &&PORTB.B0==1) // Check if human is present
{
do
   {
    PORTB.RB5=0;
open_door();     // call function to open door
lcd_Out(2,5,"OPENED"); // printOPENED on the lcd screen
   } while(PORTB.B1==0) ;  // wait till no human is present
}
delay_ms(1000);
close_door();    // // call function to close door
lcd_Out(2,5,"CLOSED"); //print CLOSED on the lcd screen
  }
```

Compliance with Ethical Standards

Conflicts of Interest: Authors declared that they have no conflict of interest.

Human Participants: The conducted research follows the ethical standards and the authors ensured that they have not conducted any studies with human participants or animals.

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