Control Science and Engineering
2017; 1(1): 11-21
http://www.sciencepublishinggroup.com/j/cse
doi: 10.11648/j.cse.20170101.14

Design and Implementation of a Microcontroller Based Home Security Alert System

Ofualagba Godswill, Onyan Aaron Okiemute*

Department of Electrical and Electronic Engineering, Federal University of Petroleum Resources, Effurun, Nigeria

Email address:
swillas_solar@yahoo.com (O. Godswill), onyan.aaron@fupre.edu.ng (O. A. Okiemute)

*Corresponding author

To cite this article:
Ofualagba Godswill, Onyan Aaron Okiemute. Design and Implementation of a Microcontroller Based Home Security Alert System. *Control Science and Engineering*. Vol. 1, No. 1, 2017, pp. 11-21. doi: 10.11648/j.cse.20170101.14

Received: April 19, 2017; **Accepted**: June 12, 2017; **Published**: August 18, 2017

Abstract: This paper presents the design and implementation of a microcontroller based home security alert system. The system detects the presence of an intruder or visitor with the help of sensors and alerts the householder, both by displaying the exact distance of the individual on a liquid crystal display (LCD) and by giving out a beeping sound in the case of an intruder or ringing a doorbell in the case of a visitor. The sensors (Ultrasonic and PIR sensors) receive the signal when the intruder or visitor is around while the control program facilitated by a PIC16F877A microcontroller translates the received signal to useful information. The implemented microcontroller based home security alert system was tested at different distances. At distances within the specified range, the system displayed the exact distance and activated the buzzer and the doorbell, while at distances outside the specified range it gave no alert at all.

Keywords: Ultrasonic Sensor, PIR Sensor, Alert System, Microcontroller, Security

1. Introduction

Security of lives and property is a major challenge globally, and Nigeria is not an exception [1]. In order to protect life and property, a security system must be developed. Such a system must have high assurance. That is, it must be available, reliable and robust [2]. The need to secure our homes, industries and other related properties has been a subject of interest since the days of our fore fathers. Since then, there has been an aggressive development in the area of security. Security is one of the important concepts of the world and every country is always security conscious of her domain.

In most developing countries, the demand for increased security measures is on the rise on a daily basis, making security one of the highest basic necessities [3]. Due to the increase in crime rate, the need to have strong security architecture in both domestic and commercial vicinities is of paramount importance. Early studies have shown that burglaries seldom occur in places where an efficient, secure home security system has been installed [4]. The early men, in their effort to provide security to their household and properties, used crude measures such as stones, grasses and crude weapons to secure themselves. As the intrusion techniques by intruders outgrow such security measures and more value is added to lives and properties, more sophisticated measures were developed to ensure an intruder-proof environment. For example, in [5], an alarm system was designed, developed and implemented. The system triggers an alarm and alerts the home owner via a mobile text message if the house has been opened or an attempt has been made to open it illegally. But this system does not detect if a likely intruder is lurking around the perimeter. To improve reliability, a security system with an ultrasonic sensor module was designed and implemented as presented in [6]. But this system does not tell the exact position of the intruder from the perimeter. It only detects that an intruder is around.

In reacting to this challenge, the idea of the development of a microcontroller based home security alert system (which could also be regarded as a motion detector or an intruder alert) came into consideration as it is crucial to have a security system which would not only secure the premises but also increase the chances of capturing criminals who likely will be ignorant of the presence of such a device. In the work presented in this paper, a microcontroller based home security alert system is designed and implemented. The system presented in this work is designed to prevent the entry

of possible intruders into the home by giving out a buzzing sound when an intruder is detected. The system detects the presence of a person from a specified distance to the perimeter of the building, and then gives a beep sound which is intended to scare away the intruder, while also displaying the distance of the person on a Liquid Crystal Display (LCD). It also acts as an automatic doorbell which rings when a visitor stands at the entrance of the home. The system is inexpensive and useful in homes, small businesses, offices, warehouses, etc.

2. Design Methodology

This section presents an overview of the design calculations for the microcontroller based home security alert system.

2.1. Power Supply Unit

The block diagram of the power supply unit is shown in figure 1.

The power supply unit provides the desired 12 V_{DC} and 5 V_{DC} to run the circuit. The voltage obtained from the mains line is 240 V_{AC} but the components require 12 V_{DC} and 5 V_{DC}, hence a step-down transformer is used to step the voltage down from 240 V_{AC} to 12V_{AC}. This 12 V_{AC} is rectified to 12 V_{DC} using a bridge rectifier circuit, and a filter capacitor is connected across the output of the bridge rectifier to remove ripples present in the output voltage [7]. The voltage regulator is used to supply the required voltage to the various components. A 12 V battery is also connected between the rectifier and the voltage regulator to serve as a backup power supply to the mains input.

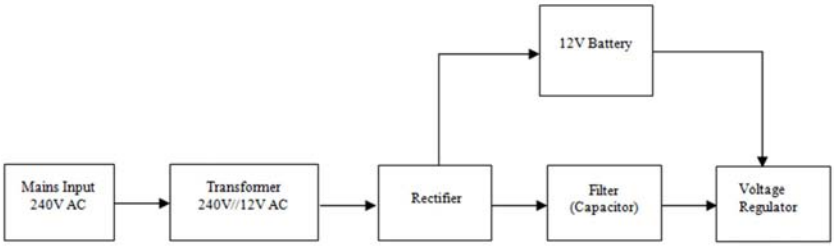

Figure 1. *Block diagram of the power supply unit.*

2.2. Sensor Control Unit

The sensing unit of this design is made up of the HC-SR04 ultrasonic sensor and the PIR sensor. The electrical parameters of the ultrasonic sensor are given as [8]:

Power supply = 5 V_{DC}
Working current = 15 mA
Quiescent current = 2 mA
Frequency = 40 KHz
Sensitivity range = 4m
While that of the PIR sensor is given as:
Power supply = 5 V_{DC}
Sensitivity range = 6m

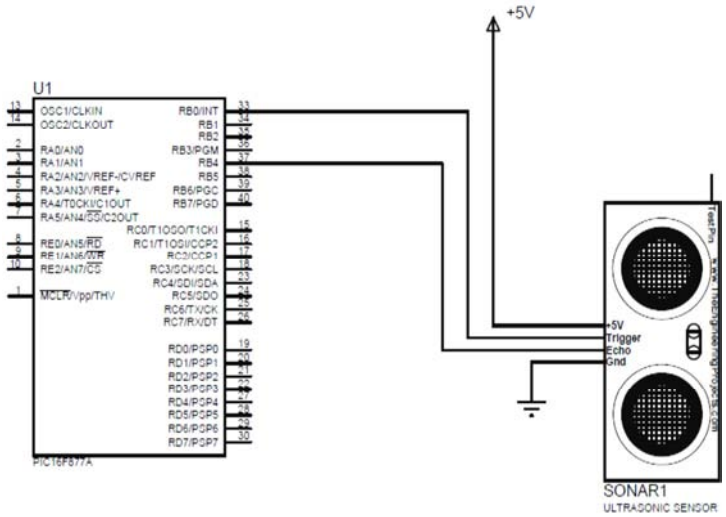

Figure 2. *Sensor control unit connected to microcontroller.*

2.3. Microcontroller Oscillator Unit

The microcontroller used is the PIC16F877A microcontroller. This is an enhanced flash microcontroller with an inbuilt flash memory of 8Kbytes and several other non-volatile memory segments, operating at a speed of 20MHZ with low power consumption (5V) and numerous peripherals to aid the programmer, thus an excellent choice capable of performing the required tasks at a very high speed without grazing its operational limits. This implies a short response time and high reliability characteristics of the design [9].

The PIC16F877A has an in-built 10-bit ADC which is used for interfacing the microcontroller to the system input. In this design, it was used for voltage sensing. The analogue input and output voltages of the stabilizer are fed to ADC pins 2 and 3, where they are converted into digital values understandable by the microcontroller. In other words, this circuit converts the analogue value into a binary number and passes it to the CPU for further processing. The result of the measurement is a number (digital value) used and processed later in the program to drive the relay switching operation and further displayed on an LCD screen.

2.4. LCD Indicating Unit

This unit displays the distance of the intruder or visitor through the 16x2 Display screen. The 8 display pins DB0 to DB7 will be connected to the input/output pins on PORT C of the microcontroller. The RS, R/W and EN are the register select, read and write, and enable signal pins respectively. Pin3 (VO) is connected to a 10k variable resistor and was used to adjust the light intensity and contrast of the LCD [10].

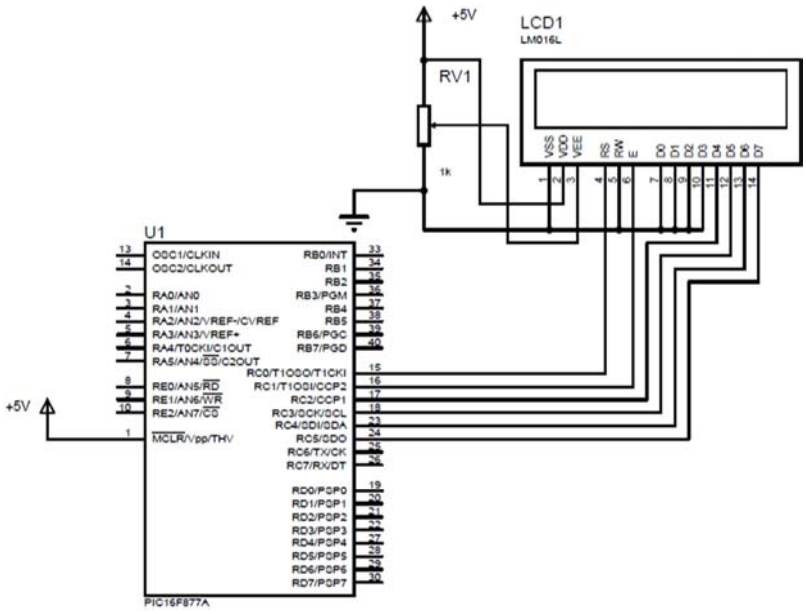

Figure 3. *LCD display unit connected to the microcontroller.*

2.5. Switching Unit

This unit is responsible for switching the doorbell and buzzer ON or OFF depending on the signal received from the microcontroller. It consists of a relay, a diode, an NPN bipolar junction transistor and a resistor.

2.5.1. Relay

The JQX-30F (T91) relay is used in this design. It has the following specifications:

Coil voltage = 12 V_{DC}
Coil resistance = 155Ω
Switching capability = 30 A
Power consumption = 0.9 W
The coil current is calculated from equation 1.

$$I_c = \frac{V_c}{R} \quad (1)$$

Where V_c is the coil voltage and R is the resistance of the coil.

$$I_c = \frac{12}{155} = 77\ mA$$

This is also the collector current of the transistor used to drive the relay.

2.5.2. Diode

Following the fact that a relay is an inductive load, a diode is used to prevent back emf from the coils. The 1N4001 is employed in this case since it has a peak inverse voltage of 1000 volts, far greater than the relay coil voltage of 5 volts.

2.5.3. Bipolar Junction Transistor (BJT)

A bipolar junction transistor is used as a switch to drive the relay in this design. It receives its biasing voltage from the microcontroller through a biasing resistor. The expression in equation 2 shows the relationship between the gain, collector current and base current of the transistor.

$$\beta = \frac{I_c}{I_b} \quad (2)$$

Where β is the transistor gain,
I_c is the collector current and I_b is the base current.
Recall, collector current = coil current = 0.077 A.
The gain of the transistor is set to 30.

$$I_b = \frac{0.077}{30} = 2.57\ X\ 10^{-3} = 2.57mA$$

The value of the resistor that will limit the base current with respect to the supply voltage from the microcontroller to the base of the transistor can thus be derived with equation 3.

$$R = \frac{V_{cc} - V_{be}}{I_b} \quad (3)$$

Therefore, $R = \frac{5-0.7}{2.57\ X\ 10^{-3}} = 1673\Omega$

For availability sake, a 10 KΩ resistor is used. The transistor used is the 2n222a transistor.

2.6. Flow Chart of the System

The design flow diagram in figure 4 shows the flow of algorithm programmed into the microcontroller. It illustrates the command given to the chip as input and the output given out.

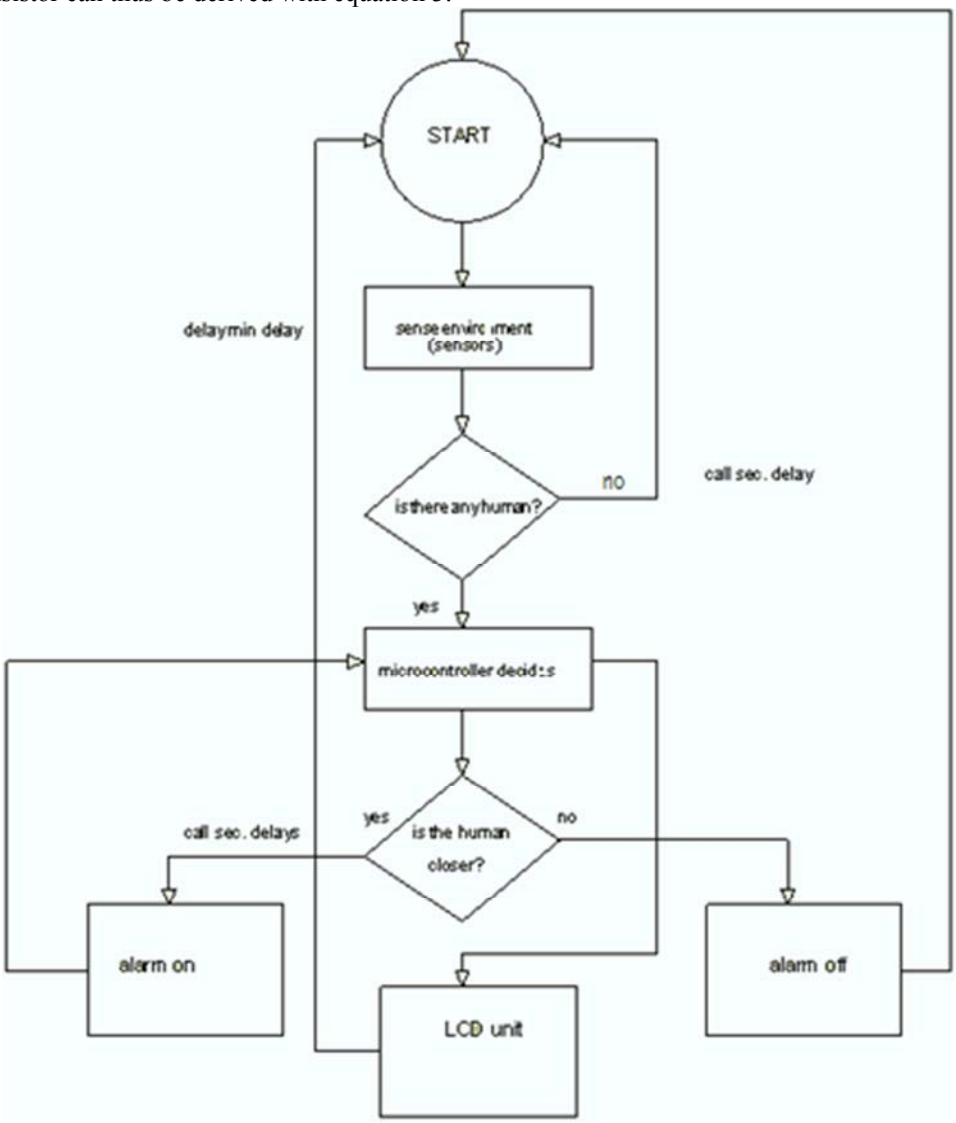

Figure 4. *Flow chart of the microcontroller based security alert system.*

2.7. Mode of Operation

The system detects the presence of an intruder or visitor around the perimeter up to a distance of 4 m using an ultrasonic sensor which emits radio waves. The person's exact location is displayed on an LCD. The system is designed to give a beep sound only when the ultrasonic sensor detects the presence of a person within 2 m of the perimeter. As the person gets closer, the beeping rate increases and the corresponding distance is also displayed on the LCD. Also, when the PIR sensor positioned at the gate entrance detects the presence of a visitor for up to five (5) seconds, the system automatically rings a doorbell.

Three ultrasonic sensors are placed facing different directions around the perimeter of the building. When an intruder is sensed, the sensors send the signal to the

microcontroller unit which processes the signal and activates the LCD to display the exact distance of the person from the building. As soon as the intruder gets close to a distance of 2 m, the microcontroller activates the buzzer through an NPN transistor Q1 connected to a 5V relay RL1 which helps in switching, and the buzzer gives a beeping sound which increases as the person gets closer to the building. The loud buzzing is intended to scare away the intruder. The PIR sensor PIR1 controls the doorbell depicted as the sounder LS1 and it activates it through an NPN transistor Q2 connected with a 5V relay RL2 which helps in switching. The doorbell would only come ON if the PIR sensor senses a person in front of it for up to 5 seconds.

The circuit diagram of the microcontroller based home security alert system is shown in figure 5.

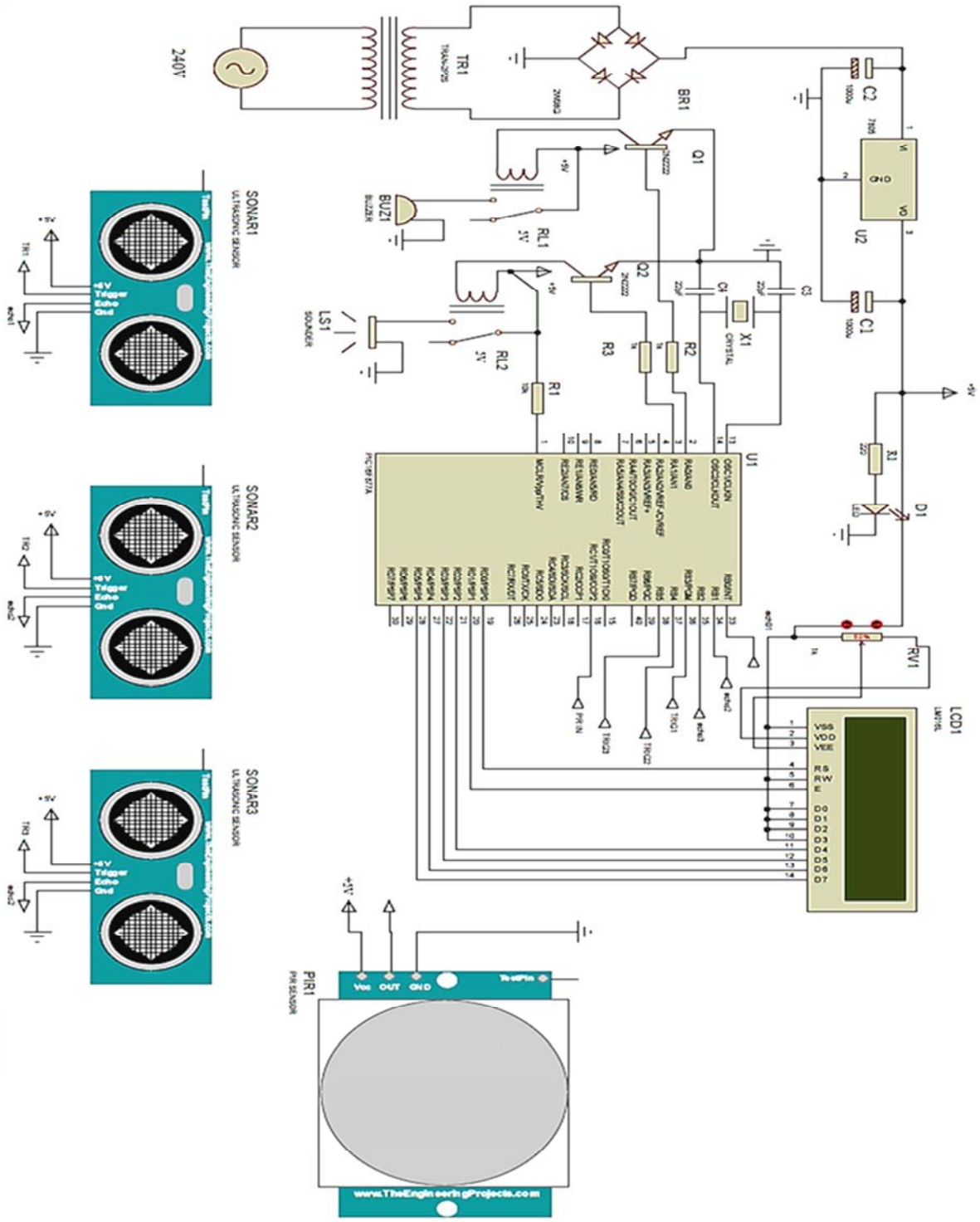

Figure 5. *Circuit diagram of the microcontroller based home security alert system.*

3. Implementation

After the design, the system was first simulated using Proteus version 7 before the actual construction was carried out.

The program for the PIC16F877A microcontroller used in this design was written in C language and compiled with the Mikro C Pro for PIC compiler, after which it was programmed into the microcontroller and simulated on Proteus environment. Since the system was designed to detect the presence of a person around the perimeter of the home for up to a distance of 4m, the Proteus simulation was done for different distances within the specified range and outside the range. Figures 6, 7 and 8 show the simulation diagrams for distances of 18 cm, 177 cm and 401 cm respectively.

After the simulation, the circuit was implemented on a Vero board. The Vero board was first inspected to ensure there were no wrong linkages between the dotted lines. Components were placed on the plain side of the board, with their leads protruding through the holes. The leads are then soldered to the copper tracks on the other side of the board to make the desired connections. After soldering each unit, continuity test was carried out to ensure that proper soldering was done. The soldered circuit was housed in a Patrex Box as shown in figure 9. The Patrex Box houses the entire circuit excluding the ultrasonic and PIR sensors which are connected externally.

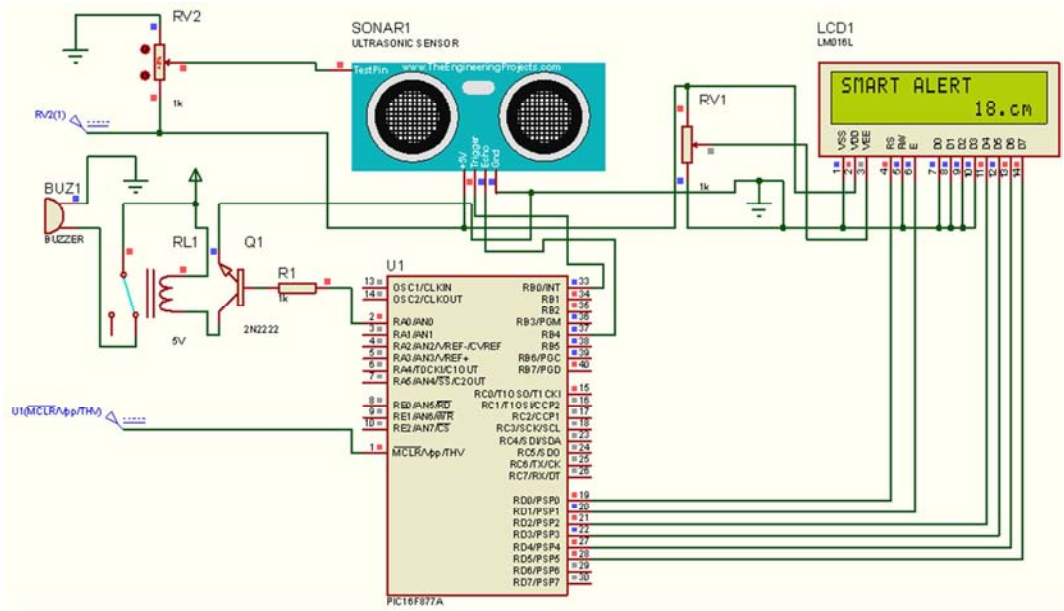

Figure 6. *Simulation diagram of the system when the input is 18 cm.*

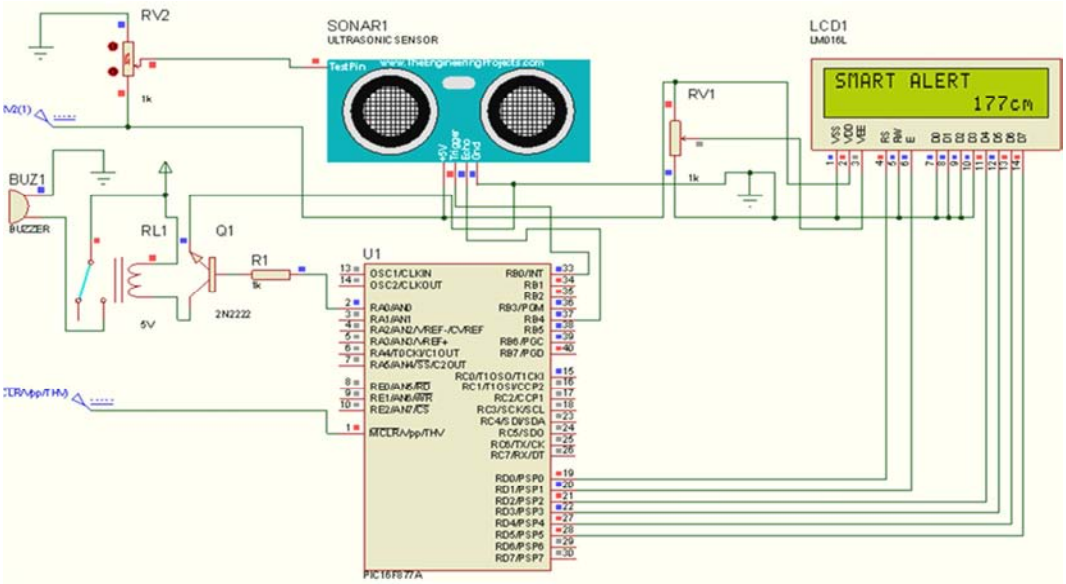

Figure 7. *Simulation diagram of the system when the input is 177 cm.*

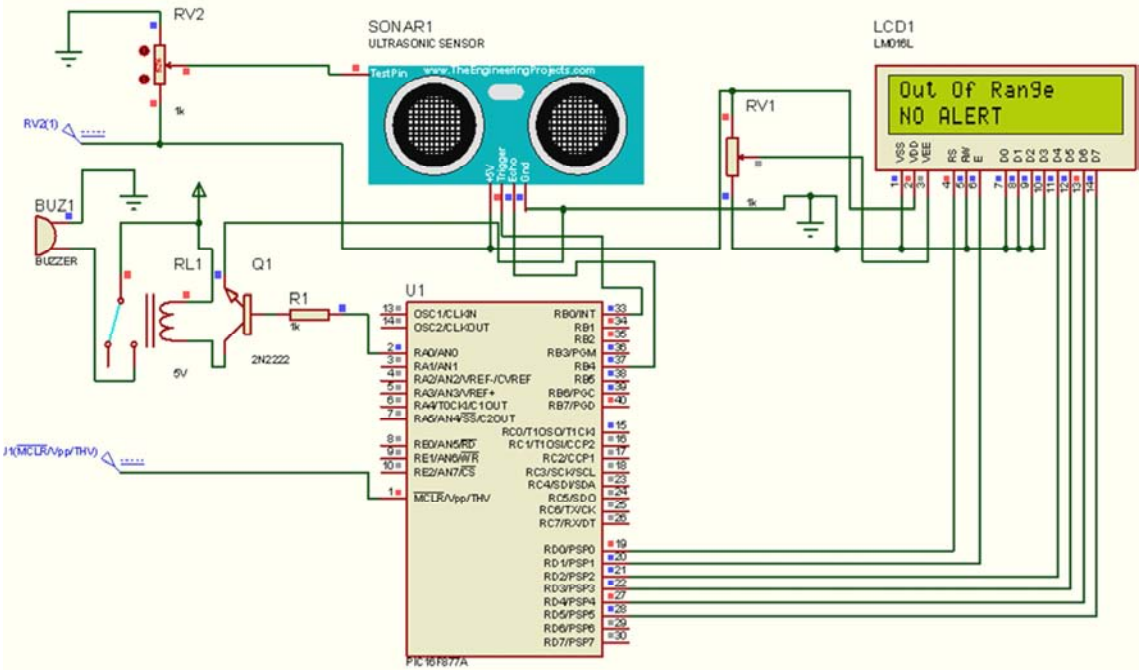

Figure 8. *Simulation diagram of the system when the input is 401 cm.*

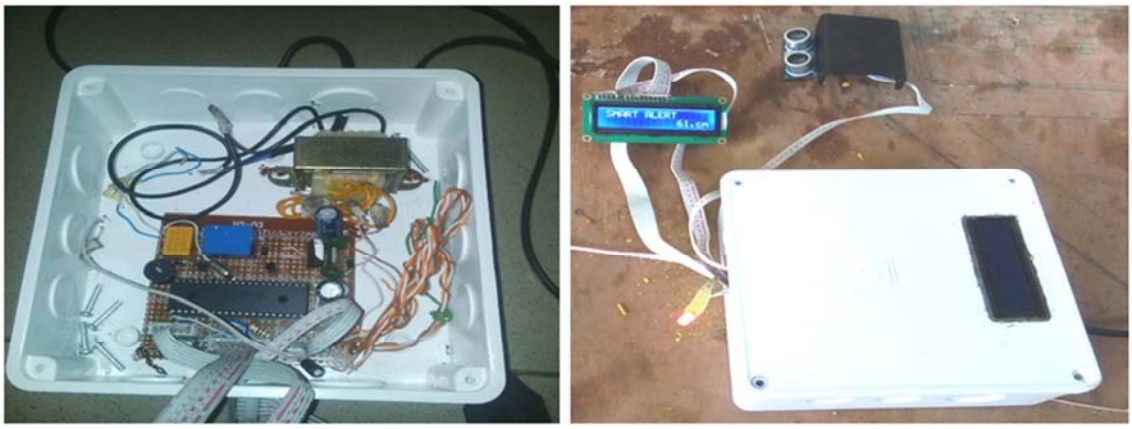

Figure 9. *The soldered circuit housed in a Patrex Box.*

The Patrex Box was then put in a house model to depict its usability in a real life situation, as shown in figure 10.

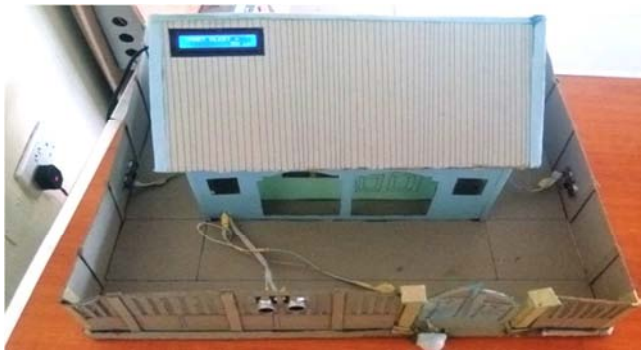

Figure 10. *A model house with the microcontroller based home security alert system installed.*

4. Performance and Evaluation

The performance of the microcontroller based home security alert system was evaluated using the responses obtained from the action of both the ultrasonic sensors and the PIR sensor.

4.1. Ultrasonic Sensors

An intruder was positioned at different distances from the ultrasonic sensors. The corresponding responses from the buzzer and LCD display for the different distances were noted and recorded. The result of the test using the ultrasonic sensors is presented in table 1.

Table 1. *Test result showing the performance of the system using the ultrasonic sensors.*

Test number	Actual distance of the intruder from the sensor	Detected distance displayed on lcd	Buzzer response	Beeping sound
1	Below 2 cm	Out of range	No alert	No beeping sound
2	10 cm	10 cm	Alert	
3	12 cm	12 cm	Alert	The beeping sound is high and the rate at which it is beeping is fast
4	15 cm	15 cm	Alert	
5	20 cm	20 cm	Alert	
6	35 cm	35 cm	Alert	
7	40 cm	40 cm	Alert	
8	61 cm	61 cm	Alert	The beeping sound is lesser than at 20 cm and the beeping rate is reduced
9	70 cm	70 cm	Alert	
10	88 cm	88 cm	Alert	
11	92 cm	92 cm	Alert	
12	100 cm	100 cm	Alert	
13	115 cm	115 cm	Alert	The beeping sound is far lesser than the above distances and the beeping rate is slower
14	126 cm	126 cm	Alert	
15	135 cm	135 cm	Alert	
16	140 cm	140 cm	Alert	
17	155 cm	155 cm	Alert	The beeping sound is lesser compared to the above distances
18	164 cm	164 cm	Alert	
19	181 cm	181 cm	Alert	
20	204 cm	204 cm	No Alert	
21	216 cm	216 cm	No Alert	
22	228 cm	228 cm	No Alert	No beeping sound above 200 cm
23	236 cm	236 cm	No Alert	
24	248 cm	248 cm	No Alert	
25	401 cm	Out of range	No Alert	No beeping sound

As shown in table 1, the system did not respond when the distance is below 2 cm because the sensor cannot sense any distance below 2 cm. But as from 2 cm, the intruder was detected. The LCD displayed the exact distance and indicated an ALERT response while the buzzer gave a beeping sound. The Alert response continued until the intruder was positioned at a distance above 200 cm (2 m). At that point, there was no alert; it is simply the distance that was displayed on the LCD. The distance continues to display until it was above 400 cm (4 m) which is the maximum range of the ultrasonic sensor and an OUT OF RANGE response was displayed on the LCD. The pictorial representations of the LCD displays at some selected distances are shown in figures 11 to 16.

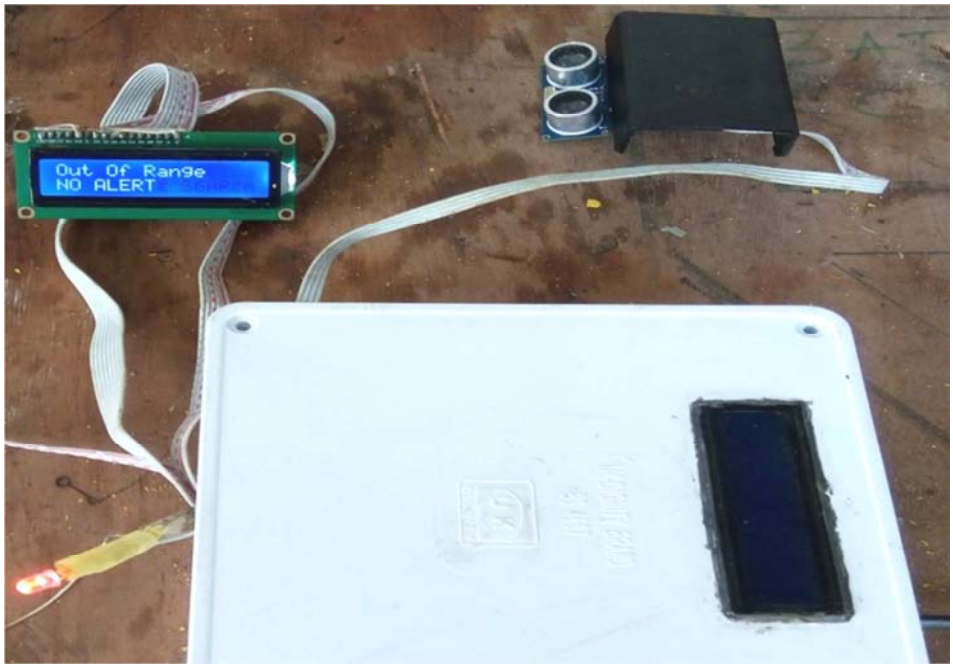

Figure 11. *LCD display at distance below 2 cm.*

Figure 12. *LCD display at distance 10 cm.*

Figure 13. *LCD display at distance 88 cm.*

Figure 14. *LCD display at distance 181 cm.*

Figure 15. *LCD display at distance 204 cm.*

Figure 16. *LCD display at distance 401 cm.*

4.2. PIR Sensor

The performance of the PIR sensor was also tested to detect the presence of a visitor. A visitor was stationed in front of the sensor for up to 7 seconds during which time the response from the sounder was noted and recorded. The result of the test is explained below.

The PIR sensor is permanently ON so a relay was used to switch it off for a period of 5 seconds to depict a delay. After the 5 seconds, the PIR sensor is switched ON to detect the presence of a visitor and when a visitor is detected, it immediately triggers the buzzer to alert the occupant of the presence of a visitor and the sound continues for 3 seconds after which the PIR sensor is switched off for another 5 seconds and no alert is given during this period. It is turned ON after the 5 seconds delay for another 3 seconds and the alert is sounded if the visitor is still present. But if no visitor is detected when the PIR sensor is turned back ON, then the sounder does not give any alert and the PIR sensor just continues radiating.

5. Conclusion

The objective of this paper, which is to design and implement a microcontroller based home security alert system, is achieved. The implemented home security alert system is capable of detecting when an intruder is lurking around the perimeter and it also serves as an automatic doorbell to indicate the presence of a visitor. The microcontroller based home security alert system was tested a number of times and performed as expected.

References

[1] Ijemaru G. K., Adamu M. Z., Yaduma S., Adedayo K. B. and Olusuyi K. O. (2014). Design and Construction of an Automatic Triggered Bell Ringer Circuit. Innovative Systems Design and Engineering, 5(12), 91-99.

[2] Autunes R. M., and Grilo F. L. (2009) Intruder Alarm System: The Road Ahead. Advanced Technologies, Kankesu Jayantha Kumaran (Ed.).

[3] Onuah F. (2013). Nigeria gives census result, avoid risky details. Retrieved September, 2016 from today reuters website: http://todayreuters.com.

[4] Cognigen Networks, Inc. (2007). Home Security System. Retrieved July, 2016 from Cognigen Networks website: http://cognigen.net.

[5] Ashraf E., Jorge H., Juan C. G., Mario R. and Francisco M. (2011). Design and Development of a House-Mobile Security System. Journal of Engineering. doi: 10.4236/eng.2011.312151.

[6] Shinu N. Y., Vince T. V., Don K. T. and Ram P. T. (2013). Security System Based on Ultrasonic Sensor Technology. IOSR Journal of Electronics and Communication Engineering (IOSR-JECE), 7(6), 27-30.

[7] Theraja B. L., and Theraja A. K. (2005). A Textbook of Electrical Technology. New Delhi: S. Chand & company Ltd.

[8] Ultrasonic sensor. (2015). Retrieved September, 2016 from Adafruit website: www.adafruit.com.

[9] Microchip (2003). PIC16F87XA Datasheet. Microchip Technology Inc.

[10] Vishay M. (2002). LCD-016M002B Specification Datasheet, Document Number: 37217. Retrieved September, 2016 from http://www.engineersgarage.com/electronic-component/16x2-lcd-module-datasheet.