



DEVELOPMENT OF WIRELESS BASED HOME SECURITY SYSTEM USING PIR SENSOR

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Abstract

Abstract: The explosion in the world population in contrast with the high level of unemployment has endangered the nations as a result of perpetual insecurity vis-à-vis, incidences of human intrusion, burglaries, and crime in private and public places has become a nightmare in Nigeria. These have propelled the urgent need to develop a home security system which can detect an intrusion via sensor and trigger alarm, however, user who is away from home cannot get immediate notification of alarm incident as done by previous work, but a Global System for Mobile Communication (GSM) with wireless technology-based Security system has been incorporated to overcome the problem. This paper presents a development of a security system that triggers an alarm upon the detection of an intruder and sends alerts via a SMS to whoever is in charge or security personnel. The system integrates sensor via a microcontroller such as Passive Infrared (PIR) sensor to detect an intruder and sound an initial warning for 30 seconds while awaiting the user response (system deactivation) in case of false intruder. Lack of feedback clearly indicates true intruder and the system eventually trigger an alarm and sends an (SMS) Short Message Service alert (predefined message which is embedded within microcontroller) to the user or security personnel through GSM module. The 4x4 Matrix Keypad is used to give command and the password to the microcontroller unit (MCU), which enables the MCU to verify the input from keypad with stored password to interface with peripheral device, upon the input of the correct password, the user can only make the system activated or deactivated. The system make use of PIR sensor, Peripheral Interface Controller (PIC) microcontroller, and GSM modem and hand phone as main components. The simulated result shows a recognition accuracy of the implemented home security system to be 99.4%

Keywords: *Global System for Mobile Communication, Microcontroller Unit, Peripheral Interface Controller, Security system, Short Message Service.*

1.0 Introduction

Security is the condition of being protected against danger, loss, and criminals, individuals or actions that go or act against the general rules of protection are responsible for the breach of security, [3]. Security can also be seen as: a condition that results from the establishment and maintenance of protective measures that ensures a state of inviolability from hostile acts or influences, with respect to classified matter, the condition that prevents unauthorized persons from having access to official information that is safeguarded in the interests of national security, measures taken by a military unit, an activity or installation to protect itself against all acts designed to or which may, impair its effectiveness, [14] A security system is defined as to detect intrusion, unauthorized entry into a building or a protected area and deny such unauthorized access to protect personnel and property from damage, loss or harm. Security systems are mainly used in residential, commercial, industrial, and military properties for protection against burglary (theft) or property damage, as well as personal protection against intruders, [1], [30]. The issue of security threat (assassination, herdsman killing, kidnapping, and theft) around country, Nigeria. Many houses, banks and schools are burgled mainly by means of illegal entry, such as breaking of a window or entrance through an unlocked door or an open window, [24], [6], [23]. Many modern alarm monitoring services allow users to access their home security system online via the Internet. They can check the status of their system, and even view video of their home if they have installed surveillance cameras, [7]. Recently, in India, a video clip system has developed a way to transfer the video stream to a mobile phone through Ethernet from PCs. A new kind of wireless image system provides users with the image information by means of a Multimedia Message Service (MMS) [2]. After so many reviews main focus were given on GSM

based home security. Basically, it is installed over the entry doors and that doors consist of (PIR) motion sensor which is connected to PIC. Signals will generate via relay and sends it to PIC18F2455 Microcontroller and action takes place according to piece of code written in the chip and GSM module sends message to owner's phone. The aim of this work is to fill this gap by presenting a system with a high security level and a low cost. This Home mobile security system (HMSS) solves the problem related to the false alarms found in other systems by integrating two sensors into one unique system.

2.0 Intrusion System

Intrusion alarms are as old as the silicon age. The truth is, the concept of an alarm system is one that was invented long before now. For thousands of years man has used animals, most notably the dog, to guard and alert people of anyone trying to tamper or steal his valuables. In the middle Ages large gongs were used to warn a population of impending doom or large bonfires lit to warn of imminent invasion, [15], [13]. These early alarm systems continued to make use of simple electrical circuits and relays. This technology allowed smaller units integrated with microwave and ultrasonic motion sensors along with features such as entrance and exit delays to be introduced, [4]. A central controller-based home security system looks to improve the security of the homes in a locality by combining many homes into a security network with a control node dedicated for each locality depending on the number of users. These control nodes are controlled by a few central or chief control nodes with considerably high processing power. The security system described by [28], [27] called Home Security System on Intelligent Network (HSSIN), uses such a central controller-based approach. The system lacks modern security parameters. A central controller based security system has its own unique challenges which include: (i). All or most homes in the neighborhood have to join in for the approach to be cost effective and successful. ii. The main question has to be considered here is who controls or has access to the central controller and its data? The central controller will be able to know about a home's intimate and private information from the data at its disposal, like if a home's room heater is on, or if an inhabitant in a home is taking a shower. This raises serious privacy concerns. [13] Developed a security system alerting via SMS using vibration sensor, PIC16F877 microcontroller, and GSM modem and hand phone. This system was designed to detect single intrusion, which can be classified as point detector as it can only indicate intrusion at a specific point. [16]. Design and implementation of a web-based home controller security system by [13]. The architecture of a web based system as shown in Figure 1.0 Web server governs the interfaced webpage that allows user to control the system. The monitoring of home condition is done over web browsers through the use of: laptop, personal digital assistant (PDA) or internet-enabled mobile phone. Laptop is connected to internet via wired local access network or wireless local access network (WLAN). PDA gets connected to internet via WLAN. Internet-enabled mobile phone is connected to an internet service which is provided by a mobile service company. When a sensor detects abnormal incident, an alert message is sent to user through web page, [13], [8]. The house owner gets to confirm the alarm after observing home condition for true abnormal incident through installed camera. Web based system makes use of high cost devices such as personal computer, laptop or PDA.

1.

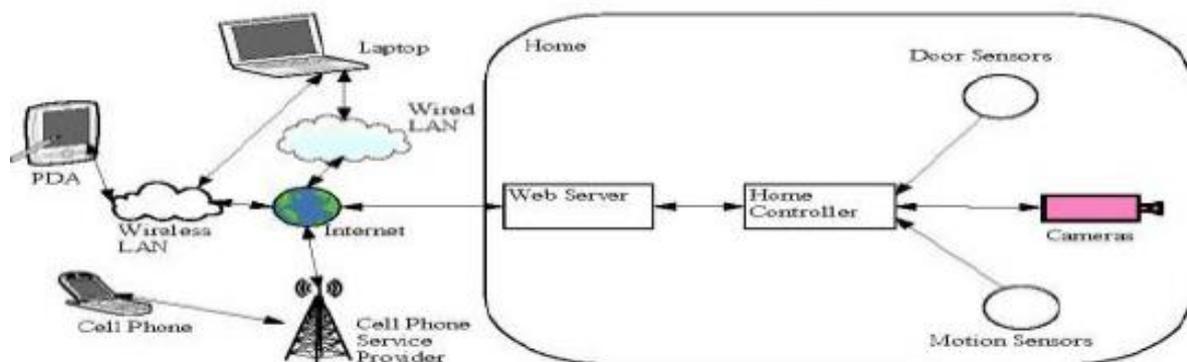


Figure 1: An illustration of Web based Home security system (Source: Cheng, (2013))

[22] Developed a security system that will alert the user through SMS. Throughout the system, user will be alerted if intrusion occurred within compound area of attached sensor. This system used one sensor, microcontroller, and GSM modem and hand phone as main components. Security system applied is fully wired technology. Implementation of GSM modem technology is function to improve the security system by sending alerting message to user as they are away from that compound area. The system was designed to detect theft, fire leakage and alarm remotely but the system cannot alert the owner remotely. There is lack of flexibility, scalability in the system, high cost implication for maintenance and limitation of distance location. [17], [11], proposed a security monitoring system based embedded and Zigbee. A combination of Zigbee and GSM, PIR vibration and magnetic sensors installed at window and door along with Zigbee end device to the present of unauthorized person in a restricted area. The limitation of the work was that it incurred access delay, and the technology used Zigbee range 50m only and data transmission rate was very low. [3], proposed a home automation Security System called Smart Eye using General Packet Radio Service (GPRS). Smart Eye also uses a central controller, to which many individual home controllers were connected. The system was a real-time home automation and monitoring system. The system alerts the homeowner by mobile phone using GPRS, and the user can view the home using live camera feeds. Understanding the context of a particular action by the user could go a long way in improving a home's security. [9], defined context as "Any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves." In a context-aware home automation system, the system tries to be aware of the context in which a user makes a decision. Predicting the location of a user inside the home adds to defining the context. [27], discussed different techniques for identifying the location of a user at home. This works used of an infrared grid to accurately predict the position of the user in the home, thus contributing to improved security. But this grid of infrared sensors is difficult to implement in a home environment. The work also discusses the use of badges to identify the location of inhabitants inside the home. This could significantly improve security, but it is inconvenient for the user. Moreover, inhabitants can be careless in their home and misplace these badges, which lead to confusion in the system. Another method mentioned in the work is static object checking. It identifies an inhabitant's location by checking to see if someone is in the proximity of a static object. This method limits the flexibility of the environment, and if someone moves or changes the position of these static objects, it will be very confusing to the system. [5], [10], explained in detail why contextual sensing is difficult. The human aspect or human behavior is very difficult to predict or reason out. People tend to be unpredictable or unreasonable at times. Unlike computers, human can improvise, and tend to make impulsive decisions about their context. Context-aware computing raises a serious question of user privacy. With context-aware computing, the system has even more intimate information about the user. [21], [26] also worked on home automation system using Bluetooth that can be accessed remotely through GPRS. The researchers used a cell-phone equipped with Bluetooth connectivity as a host controller and a GSM modem that provides Internet connectivity. Home devices were fitted with Bluetooth communication adapters so that they can communicate with the host controller phone via Bluetooth. The work discusses remotely controlling and updating host controller phone via Bluetooth. The paper discusses remotely controlling and updating home devices along with fault diagnostics and detection. The work also talks about providing an electronics user manual on the phone using Bluetooth and Internet. People are already familiar with the technology. The hardware required for establishing Bluetooth communication is readily available. And the technology also provides the necessary bandwidth for operation in homes. [25] discussed Internet or IP protocol-based communication in home automation systems; this is always a popular choice among researchers. The Internet is easily scalable, flexible when it comes to access and use, and very popular as a communication method in today's world, so the hardware and the network required for access is readily available, offers high bandwidth and very low communication cost, and devices can connect to and disconnect from the network easily. These are some of the features that make the Internet such an attractive choice for researchers.

3.0 Methodology

This section describes the methodologies used for the design of the hardware and software parts. The main hardware parts are the motion sensors and how it is interfaced to the microcontroller and the GSM interface. The model and methodology, considerations/ specifications of the intrusion detection system, its functional components and the development stages and modes of operation of the software application developed for the hardware, were discussed.

3.1 System Design steps

The Intrusion Security System consists of mechanical, electrical, and electronic components, which are integrated to complete the system design, as follows: Microcontroller, PIR Motion Sensor, GSM module, Crystal Oscillator, Comparator (LM358), Transistor (BC547), Light Emitting Diodes, Liquid Crystal Display, Resistors Capacitors, Battery (12V), Voltage Regulator (LM7805), Buzzer, and Keypad. The hardware of the system consists of the PIC18F2455 microcontroller, GSM module, sensor, Proximity sensor and GSM phone, Buzzer, and other components which its design was carried out on the manufactured breadboard mainly surface mounted components, in-system programmer, and relays to control the appliances. The sensor unit comprises an integrated circuit module such as a PIR motion sensor which is placed in front of the design. This integrated circuit is powered using 5 volts dc power source. A signal is sent to the microcontroller each time infrared is detected from the intruder’s body and the necessary actions are taken based on the program written to the microcontroller. The PIC will be thus programmed. The power source was obtained from a 12volt battery. The microcontroller and other digital integrated circuits use 5 volts for their operation and as such, a voltage regulator will be used to regulate the 12 volts power supply to 5 volts for use by the circuit. The block diagram of the design is shown in Figure 2.

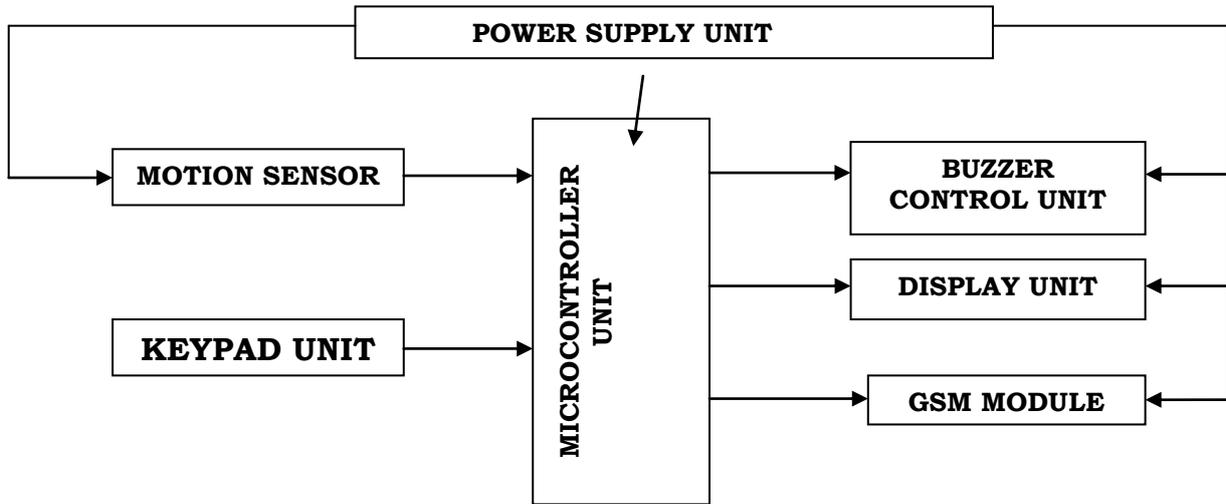


Figure 2.0: Showing the Block Diagram of an Intruder Detection and Alert System

The block diagram shows how the following units were integrated;

- (i) Detection Unit (ii) Microcontroller unit (iii) GSM Module unit (iv) Alarm unit (v) Display Unit

The power supply section is very important for all electronic circuits. The system requires 5 volts dc. This voltage level will be obtained from the 12v battery. The 12v is stepped down by voltage regulator to deliver a secondary output of 5V, 1 A. The 12v battery output is rectified by a full-wave rectifier comprising diodes D1 through D2, filtered by capacitor C3 and C4 regulated by IC7805 (IC) Capacitor C3 bypasses the ripples present in the regulated supply. The power supply schematic is shown Figure 3.0.

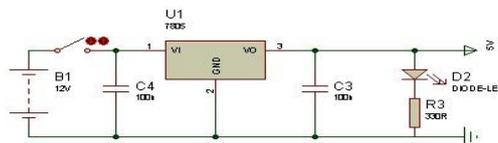


Figure 3.0: showing the interfacing Power Supply

3.1.1 Detection Unit

As shown in the Figure 4.0 of an infra-red transmitter/detector, the transmitter transmits pulse signal at a frequency of 36KHZ to the receiver in the line of sight arrangement. The receiver receives this pulse signal at an operating frequency of 36KHZ. This pulse signal made the infra-red receiver pin high or at logic 1. Once this pulse is broken, it made the receiver output low. This low signal is then sent to the input pin of the microcontroller which made the microcontroller perform the predefined task indicating an intrusion. The 10kΩ potentiometer is used to set a reference voltage for the comparator. The inverting input of LM358 is set at the middle of the 10kΩ potentiometer such that the reference voltage is giving as:

$$V_{ref} = \frac{5 \times V_s}{10} \dots\dots\dots (1)$$

$$V_{ref} = \frac{5 \times 5}{10} \dots\dots\dots$$

.. (2)

$$V_{ref} = 2.5V \dots\dots\dots$$

(3)

The high voltage level output of 3.3v from PIR motion sensor is fed to the non-inverting input of the comparator LM358, which compares it with the reference voltage of 2.5v fed to the inverting input of LM358. As long as the 3.3v output from the PIR sensor is greater the reference voltage of 2.5v, the comparator outputs a logic one (5v) to the PIC18F2455.

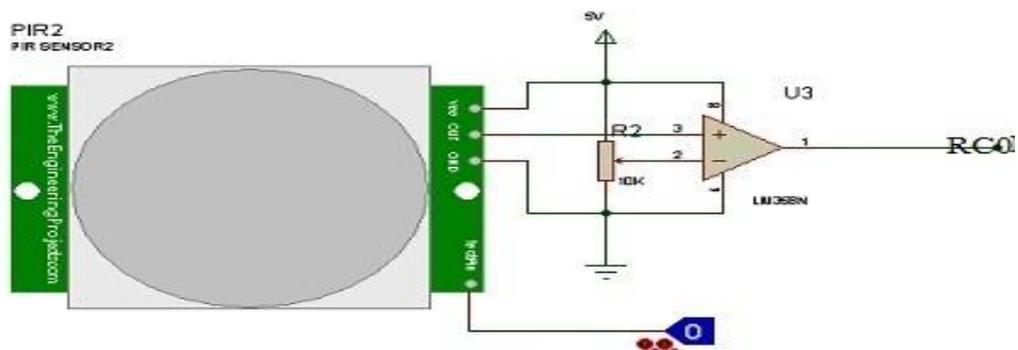


Figure 4.0: showing the intrusion detection

3.1.2 PIC 18F2455 Microcontroller unit

The control module was built with the microcontroller IC. The central controller is the PIC 18F2455 MICROCONTROLLER. The PIC18F2455 microcontroller hardware circuit is usually a flexible, low power, high-speed FLASH/EEPROM using CMOS technology. PIC18F2455 Microcontroller features 128 bytes of EEPROM data memory, self-programming, reset resistor 8.2 KΩ to 15 KΩ, an LCD, 2 comparators, 5 channels of 10-bit Analog-to-Digital (A/D) converter. The 2-wire inter-integrated Circuit (I2c) bus and a Universal Asynchronous Receiver Transmitter (USART) was used, PIC microcontroller datasheet, (2012).

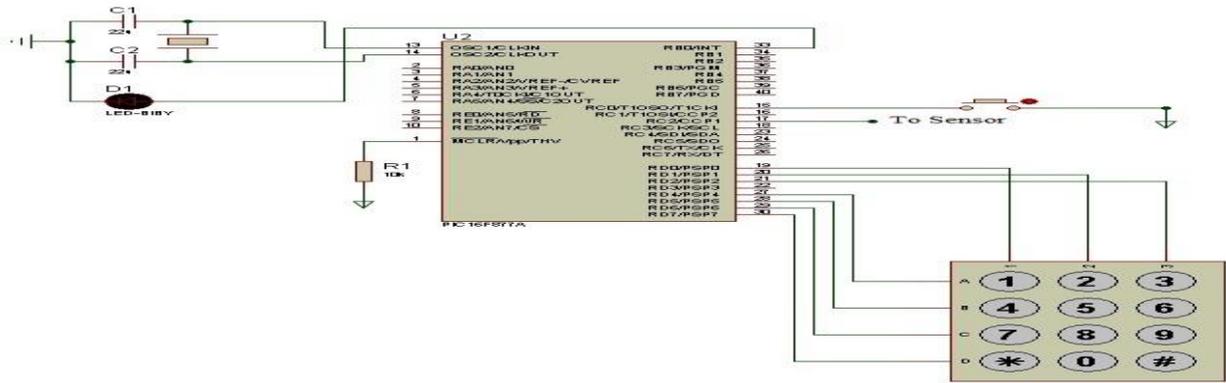


Figure 5.0: Control Circuit Design

3.1.3 GSM Modules Unit

The GSM module unit is built using the SIMCOM SIM 900 modem that specialized for microcontroller and support GPRS technology for satellite navigation. This module takes care of all GSM/GPRS based communication requirements as well as provides live GPRS data. The GSM Module SIM900A can be directly interfaced with PIC Microcontrollers, through the three lines; TX, RX, GND. The transmit signal of the serial port of the microcontroller is connected with the transmit signal (TXD) of the serial interface of GSM Modem while receive signal of the microcontroller serial port is connected with receive signal (RXD) of serial interface of GSM modem. Figure 6.0: shows how the GSM is interfaced with PIC18F2455 microcontroller.

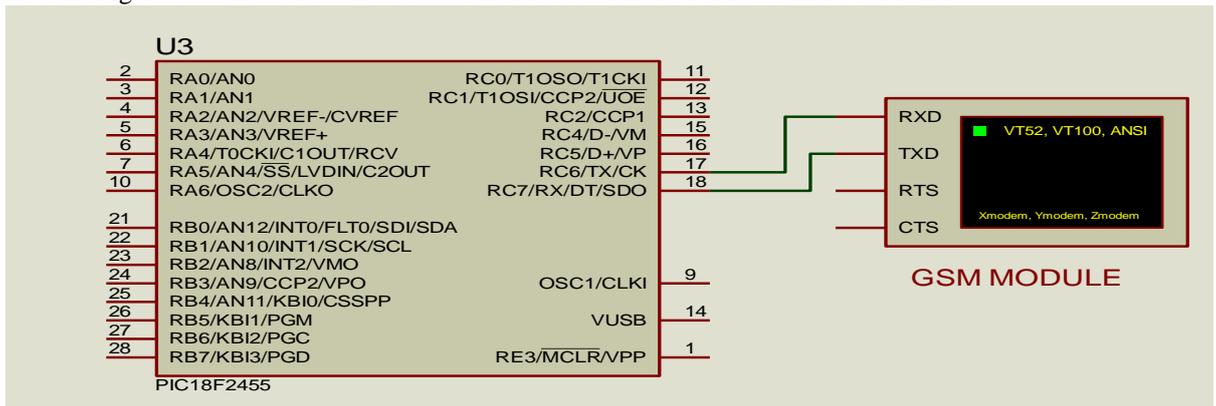


Figure 6.0: showing the Interfacing GSM module with PIC Microcontroller

3.1.4 The Display Unit

This display unit used for the design is Liquid Crystal Display (LCD) because of its ability to display numbers, character, graphics, ease of programming for characters and graphics and low power consumption. The 2 x16 character LCD has two rows of 16 characters each. The display receives ASCII codes for each character at D4 to D7 which is connected directly to the 4 PORTB pins of the PIC18F2455 microcontroller. To initialize the LCD, the Register Selects (RS) line must be set to logic 0. The 8-bit code for each ASCII character is sent in two halves; high nibble first, low nibble second. Although this makes the software only slightly more complex, it saves on I/O pins and allows the LCD to be driven using only six lines as shown in Figure 7.0.

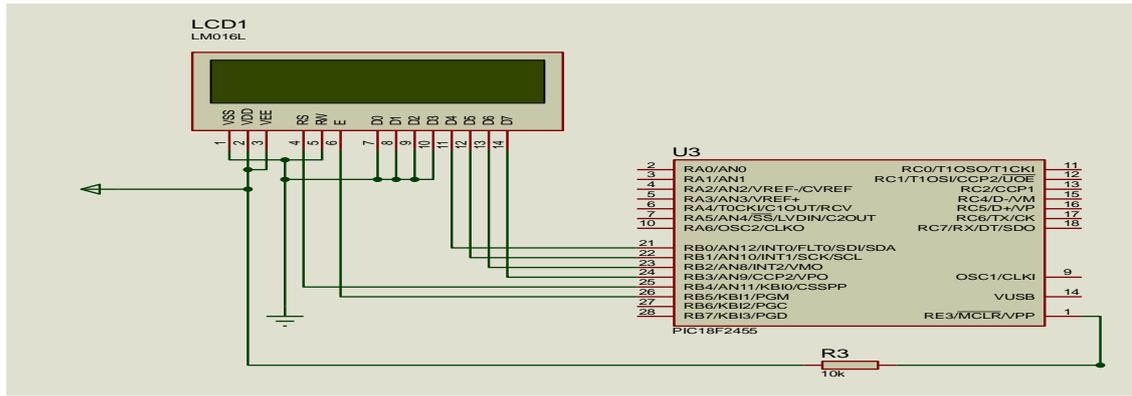


Figure 7.0: Showing Liquid Crystal Display to PIC 18F2455 microcontroller interface

3.1.5 The Design of the Buzzer Unit

The buzzer is connected to a 12volts supply and connected via a BC547 transistor to the ground. The base of the transistor is connected to the microcontroller through a current limiting resistor (10K), Figure 8.0 shows the circuit diagram of buzzer unit.

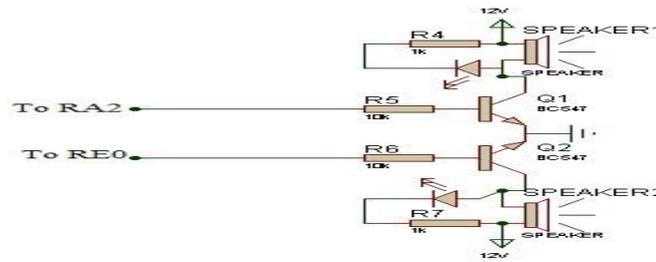


Figure 8.0: Circuit Diagram of the Buzzer Unit

3.2 Operation of Intrusion Security System via SMS

In the designed system, once the system is powered on and activated, the system starts monitoring the environment for an intruder as shown in the figure 9.0 below. When the motion sensor (PIR) detects a movement of an intruder, system sounds an initial alarm expecting the intruder to deactivate the system with the set password in case of false intrusion as shown figure 10.0 below. If the password is correct, the system is deactivated and continues to monitor the environment as shown in figure 10.0. If the intruder did not input any password within 30seconds or if the password is incorrect, the system sounds an alarm with the buzzer and displays the message “INTRUDER DETECTED” on the LCD as shown in figure 11.0. And also an SMS will be send to a predefined number which could be owner of the restricted area or security Reaction Company via GSM module as shown in figure 12.0. A keypad was used to give commands and the password to the MCU to enable only an authorized user has ability to activate and deactivate the system. When the device is turned ON, it needs to be activated by pressing the push button, then it will give only 30seconds to allow the owner to safely exit your home or sleep without triggering the alarm, within this stipulated period of time, a status of green LED will blink. After that, the status LED will stay ON to notify you that the program is in the alarm mode. In alarm mode, the program will constantly monitor the input from the PIR when motion will be detected. The reason for this short delay before activating the buzzer is because it might be the owner who might want to deactivate the alarm, 30 seconds is given to reach the alarm and switch it off or deactivate it. Once the system is deactivated, one have to press the push button again to activate it and check it the status LED is ON.



Figure 9.0: System monitoring the environment for intrusion

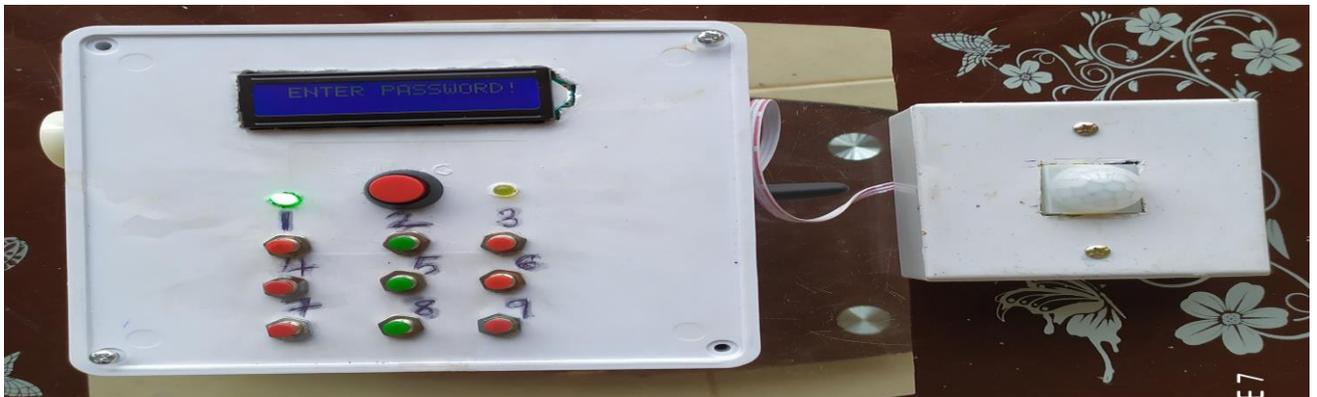


Figure 10: System requesting for deactivation password



Figure11.0 (a): Intruder detected by the system



Figure 11.0(b): SMS alert showing intruder detected



Figure 12: External view of the intrusion detection and alert system

4.0 Results

The result of simulation ensures that the circuit worked at properly. The practical implementation of simulated circuit has been presented in Figure 13.0. In this circuit diagram PIC microcontrollers was the main components used for controlling other devices (PIR Sensor Module, GSM Module, LCD Display and Buzzer). Among the controlling devices, motion sensor was used as a sensor for determining the present status of the system.

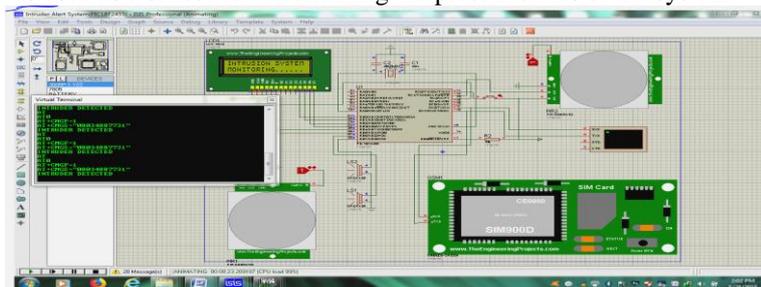


Figure 13.0: shows simulated circuit with Proteus

PIR motion sensors were placed at the entrance of the building where it is suitable to detect within the range of 7m. This signal which detects intruder presence triggers the input of the microcontroller. The owner may or may not be present will receiving the text messages by providing the alert message “There is an “intruder detected” or else the if the module is unable to send the SMS this newly proposed method launch an automatic alarm call to the concerned authority regarding the corresponding information. The overall working of the system is controlled by the mobile device. The message gives the feedback following the performance and display errors. The proper operation of the sensor requires a warm time of 30 seconds as it requires to the sensor according to the stable environment. The connectivity is provided based on the PIC Microcontroller and then communicates with GSM module via the network. The sensor which generates the electrical signals converts to GSM module using PIC microcontroller. The delay time is important aspect regarding the message to user device should be of fixed delay that was implemented through the microcontroller programming code. The issue in this system of

receiving high output signals can be reduced to low by programming of the PIC18F2455 As the PIC microcontroller board has 14 digital Input/output pins, USB connection, ICSP header and reset button. It contains everything needed support for system implementation. The system provides a user interface as it interacts with the system.

The PIR sensor responsible for the detection of motion adjusts itself to the infrared signature of its surroundings and keeps watching for any changes. In the absence of motion, the LED indicator will remain dim, and the program will continue updating the surroundings. If the sensor detects movement, the frame for motion detected will be the input frame to the process of human detection, and consequently, the motion detection indicator will light up. The result of the testing performed on the implemented system. Total values of 760 seconds at difference distance (m) were: 18, 17, 7 and 2 were obtained for delay time, Td, Ta, Fd and Fa, respectively. The average delay time was 30.4 seconds which reflects a percentage error of 0.013. It is also noteworthy to indicate that the lithium batteries used were getting weak and the batteries were replaced twice, after the tenth (10) and the twentieth third (23) attempts.

The monitoring system of this system consists of two sub-systems which are notification system and alert system. The notification system enables the user to be notified any alarm incident of home condition via SMS (Short Message Service) which is done over GSM technology. Alert system performs visual or audible responses through light emitting diode display and buzzer or siren respectively.

The following parameters were used for evaluating this developed system:

- i. False Detection (FD): This is the process whereby the implemented system detects the presence of an intruder but fail to send or trigger alarm and alert.
- ii. False Alarm (FA): This is the process whereby the implemented system does not detect an intrusion but mistakenly sends the alarm.
- iii. True Detection (TD): This is the process whereby the implemented system detects the presence of an intruder and the system sends or triggers alarm and alert.
- iv. True Alarm (TA): This is the process whereby the implemented system detects a true intruder and truly sends the alarm.
- v. Sensitivity (SE): the degree of response of the system to correctly detect or identify a true intruder.
- vi. Specificity (SP): The state of being specific for a false intruder.

$$\text{Sensitivity} = \frac{Td}{Td+Fa} \dots\dots\dots (4)$$

$$\text{specificity} = \frac{Ta}{Ta+Fd} \dots\dots\dots (5)$$

$$\text{False positive reduction} = \frac{Fd}{\text{TOTAL NUMBER OF ATTEMPT}} \dots\dots\dots (6)$$

$$\text{False negative reduction} = \frac{Fa}{\text{TOTAL NUMBER OF ATTEMPT}} \dots\dots\dots (7)$$

$$\text{Accuracy} = \frac{Ta}{Ta+Fa} - \frac{Td}{Td+Fa} \times 100 \dots\dots\dots (8)$$

This system performance better at 2-3 m and it was observed the system gave false alarm when the battery of system weak and as well unable to send alert when the intruder being detected at a very long distance but display only alert via visual or audible responses. (Visual responses is indicated by Light Emitting Diode and audible indicated by buzzer or siren. Percentage Accuracy measured SP/SE x100 = 99.4%

4.1 Discussion

The prototype were designed and implemented. The results obtained from the combination of various intrusions detection system components and corresponding constructions are evaluated and some observations were made during the different stages of testing. Some distances were taken so as to ascertain the workability of the intrusion detection system. The best line-of-sight is about 300cm the distance from the developed system and the suspected intruder. The percentage error reflected was due to internal frictions within the security system mechanism. Specificity (SE) of the developed system was 0.8947(89.47%). This implies the ability of the implemented home security system correctly detect an intruder and trigger alarm and alert via GSM Technology. Sensitivity of the implemented home security system was 0.9(90%). This indicates that the implemented home security system was able to correctly detect an intruder and trigger alarm and alert via GSM Technology to owner of the house. Nevertheless, the Recognition Accuracy of the implemented home security system was 99.4%.

5. Conclusion

The developed of an intruder detection and alert security system gives good response to the motion sensor when it detects intrusion at the restricted area. The result showed that both the switch and the motion sensor attached to the entrance performed adequately as expected. The entire decision making was carried out with the aid of a PIC18F2455 microcontroller. One of the main feature of the design, it was built with a time delay of 30 seconds to allow a false intruder (i.e. if it is the owner), inputs the right password, the system deactivates and continue to monitor the environment for further intrusion. If it is a true intruder (i.e. unknown person who does not know the password), and the person does not input the password within 10seconds or if the person inputs the wrong password, the system sounds an alarm and sends SMS to the owner or security personnel.

The research exploits the advancement in the technology of communication to provide a comfort for users. Implementing this project in every homes, implies improving the security of the home and also bringing what goes on at home closer to the owner anywhere at any time provided the GSM network is available and well reduce burglary and theft. This research design achieved all its targeted aims and accomplished its objectives successfully.

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