



Research/Technical Note

Design and Construction of an Automatic Home Security System Based on GSM Technology and Embedded Microcontroller Unit

Iyapo Kamoru Olarewaju¹, Odo Ekundare Ayodele², Fasunla Olukayode Michael¹, Egbuwalo Shadrack Alaba¹, Raimi Oluwole Abiodun³

¹Department of Science Laboratory Technology, Faculty of Applied Science, Rufus Giwa Polytechnic, Owo, Nigeria

²Department of Physics, School of Science, Federal University of Technology, Oye, Nigeria

³Department of Mechanical Engineering, School of Engineering, Federal University of Technology, Akure, Nigeria

Email address:

iyapokamoru@gmail.com (I. K. Olarewaju)

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Abstract: In wake of the number of burglar incidences rising in different states in Nigeria, and the lack of an efficient state security agency, there has been a focus on the deployment of home security/alarm systems, sponsored by different privately own security outfit in other to combat the high level of crime. With the advancement in technology particularly the Global System Mobile (GSM) technology, securing our home has never been easier. It's now possible for users to control and monitor systems and development in their household with the help of their smartphones. The development also brings in other advantages like cost effectiveness and much needed efficiency. In this project we design and construct an automatic home security system based on GSM technology and embedded microcontroller unit. The system consisted of an infrared motion detector and a magnetic sensor as transducers for detecting intruders motion or break in through a door. The signals are then processed by an embedded microcontroller unit which then activate the GSM module and send SMS message to the householders mobile phone device, at the same time activating an attached alarm system. Initial testing of this system shows that it worked as expected.

Keywords: Embedded Microcontroller, Infrared Motion Detector, GSM Module and Alarm

1. Introduction

Home monitoring and security systems are becoming common place in recent time. One of the reasons for the rise of the smart home is the increasing risk of burglary and robbery and the busy lifestyle [1]. The busy lifestyle of people is leading to the necessity of controlling the devices at home remotely and increasing the necessity of keeping surveillance over their homes. In many areas of industry especially where there is need to protect certain goods or services electronic security based on the use of embedded processors are employed. In more recent times however, the development of the Global System Mobile technology has push the frontier of electronic security to a more sophisticated level. It's now possible for users to control and monitor systems and

development in their household with the help of their smartphones. The development also brings in other advantages like cost effectiveness and much needed efficiency.

A typical home security system should consist of a detector and an alarm system which is triggered once an intruder is detected. Detector systems could be as simple as a trip switch attached to movable part like the hinge of a door and even door handles in such a way that any movement around this area will toggle the switch and thus raise an alarm. In more complex devices, detectors which can sense infrared radiation produce by body heat and fluctuation of such radiation as a result of movement have become common. Such detectors usually sense motion and then trigger the appropriate response. In other detectors, the characteristic sound produced by the

shattering of glass windows or the banging of a door is picked up by high gain capacitive microphone and appropriate filters to isolate the characteristics sound necessary to activate or trigger an alarm system. The development in embedded system design has also made possible the development of smart home security system, where the processing of signal received from a detector can be program. Such development allow for customized processes to suit specific home or industrial need.

This work tends to utilize the availability of GSM network, mobile module and electronics circuit to achieve an automated system which is programmed to work as a thinking device to accomplish this purpose. By simply sending message to the phone number of the SMS attached to a slot in the circuit, this automatically puts the system to either “active or inactive” state, and on any attempt of theft the system sends a text message to the device owner, With this, the house is always protected. The total absence of sufficient security personnel in a house is a great discomfort to house owners.

The new age of technology has redefine communication. Most people nowadays have access to mobile phones and thus the world indeed has become a global village. At any given moment, any particular individual can be contacted with the mobile phone. But the application of mobile phone cannot just be restricted to sending SMS or starting conversations. New innovations and ideas can be generated from it that can further enhance its capabilities. Technologies such as Infra-red, Bluetooth [2], ZigBee [3] and Global system for Mobile Communication [4] to mention a few, have been developed in recent years to show the very fact that improvements are in fact possible and these improvement have eased our life and the standard of living. These days, apart from the use of mobile phone for calls and messages, we make use of GSM to secure our homes from intruders by simply receiving message after a sensor device has sensed the presence of an intruder.

For home security system, [5] suggested two methods for home security which is by using web camera and GSM-GPS module (sim548c) and Atmega644p microcontroller, sensors, relays and buzzers. The design based security systems provides enhanced security as whenever a signal from sensor occurs by sending a text message to a desired number so as to take the necessary actions.

A microcontroller based temperature monitoring and logging system suitable for usage in hospitals was designed and constructed [6]. The features include ability to monitor a patient's temperature on a continuous basis while displaying the instant result on a liquid crystal display device. The designed system allows the doctor at a location from the patient to keep track of his patient's condition while attending to other issues.

In the design and construction of GSM intelligent home security system for real time monitoring of intruders, [7] came up with a design implementation in such as a way that maintenance and repairs are easily done in the faults.

In security door system, [8] presented a design and implementation of microcontroller using mobile phone and computer. The result of the design processes led to a security

door which can be accessed by entering the corresponding keys of the assigned codes on the mobile phone, or by entering the corresponding code in a computer set interfaced with the system.

In creating a system that make the surveillance of home devices easily, [9] used GSM module to communicate with the owner of the home whenever the sensor senses a fault which in turn sent specific messages to the owner in order to take a necessary action. The design was able to control and monitor temperature, smoke, intrusion motion, magnetic lock door, garage door and irrigation.

This project “GSM Based Home Security System with SMS Alert Using Human Body Motion Detective and GSM Module” is developed to build a security system for a home/office to prevent other persons to enter into the important room/chamber using GSM networks, an alert system has been proposed that will act as an embedded system which can be used to alert the owner through SMS of movement of unauthorized persons. Remotely the system allows the user to effectively monitor the house/office via the GSM module by sending commands in the form of SMS messages. However, the broad objective of the study is to design and construct an automatic home security system based on GSM technology and embedded microcontroller unit.

2. Hardware Design Considerations

This section describes briefly the different hardware used in the design as well as the software algorithm implemented in the embedded microcontroller unit. Figure 1 shows a pictorial description of the proposed home security system.

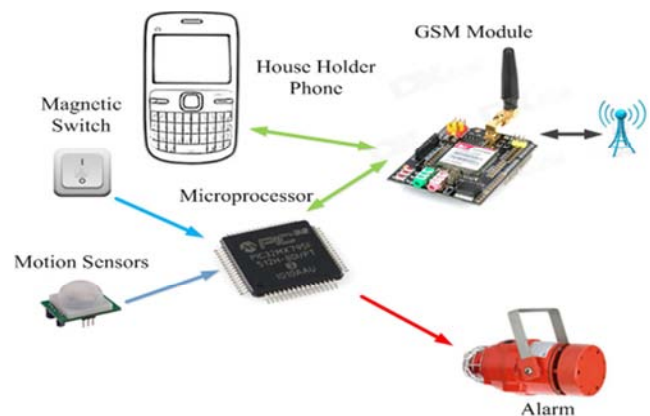


Figure 1. System block diagram.

2.1. Microcontroller and Sensor Unit

Figure 2 shows the control module built with the microcontroller IC. The central controller is the Microchip PIC18F4520. The design consisted of ICSP inputs for the programming of the microcontroller which is a connector attached to RB6, RB7 and the MCLR pin 1 of the microcontroller unit. The microcontroller also accepts input from switch sensors which can be placed on the hinges of doors or windows. Also included in the design is the PIR connector input for the motion sensor. The microcontroller is

set to operate at 20MHz by the crystal oscillator and the paired 22pF capacitors. The PORTD1 of the microcontroller is configured to control a relay attached to the alarm system. The RS232 port of the microcontroller is attached to the GSM/GPRS module for the transmission and reception of

mobile calls and SMS's. The system is powered by a 5V regulator circuit built with a LM7805 regulator IC and filter capacitors. The circuit was implemented into a double sided printed circuit board with the component connections on the top side. As shown in Figure 2:

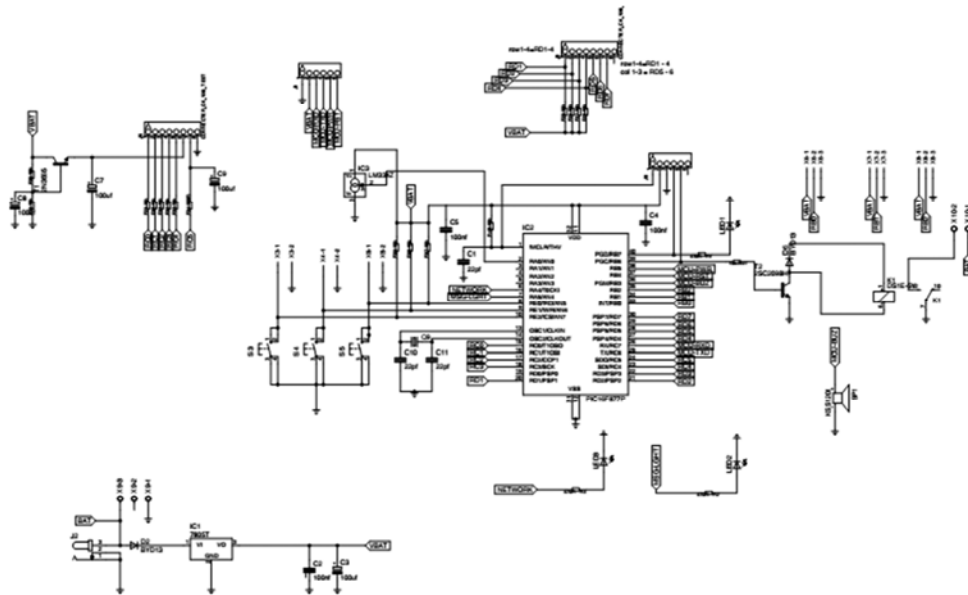


Figure 2. Showing the circuit diagram of the microcontroller unit of the system.

2.2. GSM/GPRS Module

Figure 3 shows the design of the GSM/GPRS module. It consisted of the SIM900 module as the central core. As input to the module is a switch and connector for either hardware powering of the module or software based powering. The module also consisted of a SIM card holder for the attachment of the desired network operator SIM card. The design also included a microphone and earphone jack for audio or voice

transmission and reception. The module connects to the microcontroller unit via the RX and TX pin which are dedicated for Asynchronous serial data process. The entire module is powered from a 4.2V power regulator and therefore needed voltage translator built out of transistor for smooth interchange of data. Figure 3 shows the printed circuit board design use for the production of the GSM module.

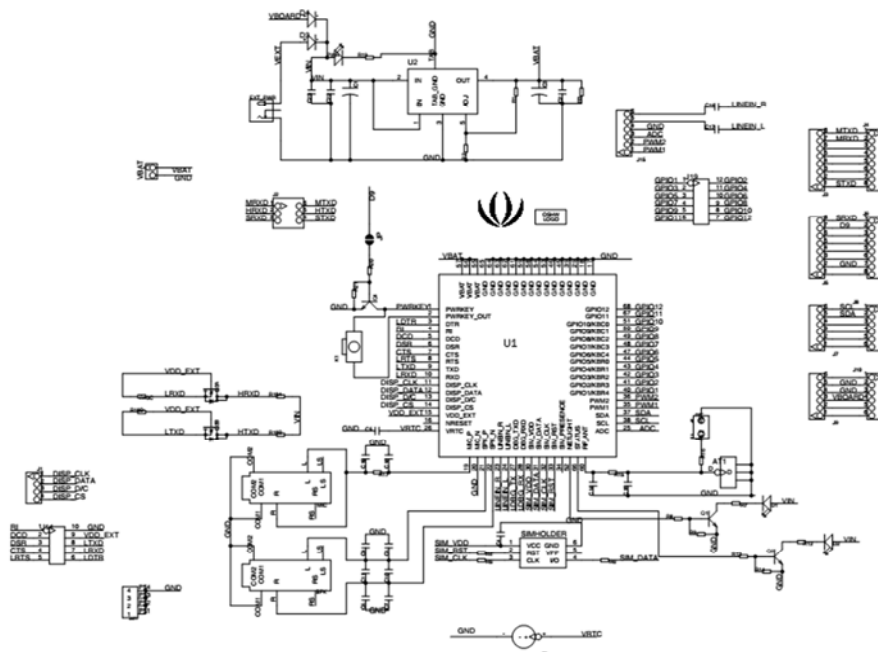


Figure 3. Showing the circuit diagram of the GSM/GPRS module.

2.3. System Description

This section describes briefly the design methodology used to achieve the project. The project was design to provide global access to the system for the security using extensive GSM technology for communication purposes and microcontroller for device control. The highlights of the system are the long range of communication and robust coordinating software with a data base containing information about the user (client) mobile phone number. Design also based on microcontroller based home security system with SMS alert using human body motion detective and GSM module. The system design is in three main phases: the sensitivity, central processing and action. The sensitivity is the perception section that is done through PIR sensor mounted at watch-area, central processing is performed by a programmed microcontroller, and the action (task) is done through an interaction of an attached on-board GSM module to the processor (the microcontroller) which then send an SMS alert to the user or owner mobile phone number [10]. This system is design to only detect only (or part of human) body motion.

2.3.1. Motion Sensor

A motion detector is contains a motion sensor and is either

incorporated with or connected to other devices that alert the user of the pre-sense of body motion. An electronic motion detector contains a motion sensor that transforms the detection of motion into an electric signal. The motion sensor used for this work is the Pyroelectric Infrared PIR Motion Sensor Detector Module shown in Figure 4. The PIR (Passive Infra-Red) Sensor is a pyroelectric device that detects motion by measuring changes in the infrared levels emitted by surrounding objects. This motion can be detected by checking for a high signal on a single I/O pin. Its special features include Single bit output Small size which makes it easy to conceal, Compatible with all Parallax microcontrollers 3.3V & 5V and operation with <100uA current draw. The Pyroelectric devices, such as the PIR sensor shown below, have elements made of a crystalline material that generates an electric charge when exposed to infrared radiation. The changes in the amount of infrared striking the element change the voltages generated, which are measured by an on-board amplifier. The device contains a special filter called a Fresnel lens, which focuses the infrared signals onto the element. As the ambient infrared signals change rapidly, the on-board amplifier trips the output to indicate motion.



Figure 4. Showing the infrared sensor used for this work.

2.3.2. The Microcontroller Circuit

In this design the PIC18F4520 microcontroller was used. The PIC18F4520 is a high-performance enhanced flash, microcontroller from Microchip with nano watt technology. This Microcontroller offers the advantages of all PIC18 microcontrollers – namely, high computational performance at an economical price with the addition of high-endurance, Enhanced Flash program memory. In addition to these features, the PIC18F4520 introduces design enhancements that make these microcontrollers a logical choice for many

high-performances, power sensitive applications. The Devices incorporate a fully featured Serial Bus communications module that is compliant with the RS232 Specification Revision 2.0. The module supports both low-speed and full-speed synchronous and data transfer types. It also incorporates its own on-chip transceiver and 3.3V regulator and supports the use of external transceivers and voltage regulators.

Figure 5 shows pin diagram of the DIL package and the block diagram of the PIC18F4520 family respectively, it

consist of a 32 Kbytes flash program memory, 13 pins 10bits A/D channels, 5 bi-directional ports, one standard capture compare port (CCP) and an enhanced capture compare port (ECCP). Other notable features for devices in this family

include 3 timer circuitry, data EEPROM and an 8 bit Arithmetic Logic Unit ALU, for data and instruction execution.

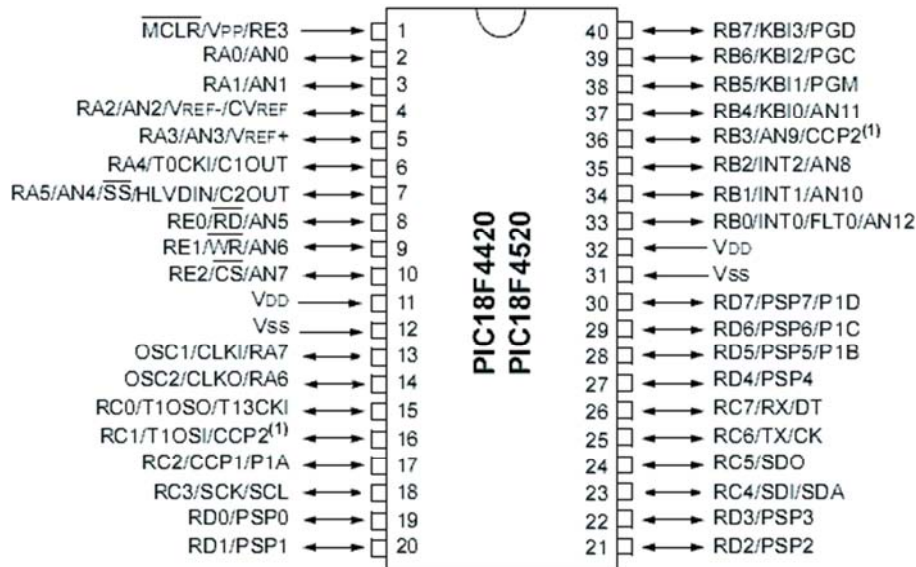


Figure 5. Showing the PIC18F4520 Microcontroller.

2.3.3. GSM Module

GSM module, Figure 6, is a specialized type of modem which accepts SIM card, and operates over a subscription to mobile operators. When the GSM modem and computer are interconnected, there is communication over the mobile network. Though these GSM modems are most used to provide mobile internet connectivity, most of them can also be used for sending and receiving SMS and MMS messages. This device can also receive and process GSM signals from virtually all GSM bands. Advantage of using this modem will be that you can use its RS232 Port to communicate and develop embedded applications.

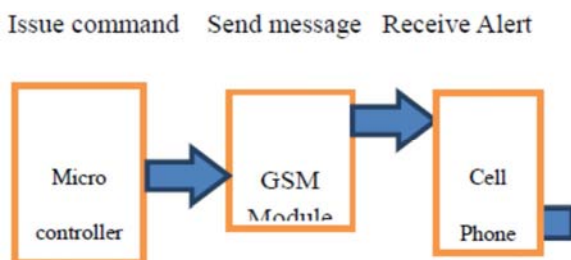


Figure 6. GSM Module Interaction.

Communicate with network GSM module and this will send Message to the user and also receive instruction from the user cell phone for reprogramming the phone number.

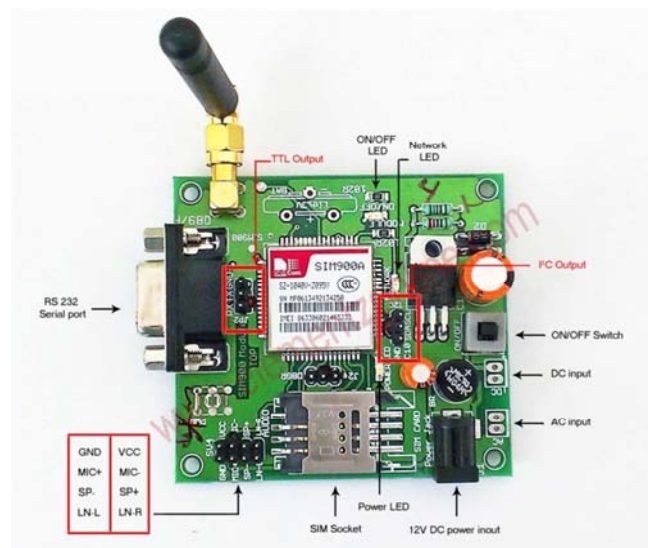


Figure 7. Showing specialized type of modem.

2.3.4. SIM900 GSM Module

The GSM module used for this work is the SIM900 GSM/GPRS module from SIMCOM. It is an ultra-compact and reliable wireless module with minimum system configuration based on a 0 Quad-band GSM/GPRS technology making it suitable for use in any part of the world.. It can communicate with microcontroller via AT commands (GSM 07.07, 07.05 and SIMCOM enhanced AT Commands). This module support software power on and reset. The GPRS is configured and controlled via its UART using simple AT commands. Figure 8 shows the GSM module used for this work.



Figure 8. Showing the GSM/GPRS module used for this work.

2.3.5. Alarm Siren

A siren is a loud noise making device. Electronic sirens incorporate circuits such as oscillators, modulators, and amplifiers to synthesize a selected siren tone (wail, yelp, pierce/priority/phaser, hi-lo, scan, airhorn, manual, and a few more) which is played through external speakers. For this project an Alarm Siren Horn Buzzer Speaker was chosen. Figure 9 shows a typical siren speaker system. The device is made of fireproof ABS material and operates at a rated voltage: DC 12V Power with an output of 15W. The sound pressure level is 110dB with a time delay of 1s.



Figure 9. Showing the Siren Speaker.

2.3.6. Light Emitting Diode (LED)

Light emitting diode is a two-lead semiconductor light source. It is a basic pn-junction diode, which emits light when activated [11]. When a suitable voltage is applied to the leads, electrons are able to recombine with electron holes within the device, releasing energies in the form of photons. An LED is often small in area (less than 1mm²) and integrated optical components may be used to shape its radiation pattern [12].

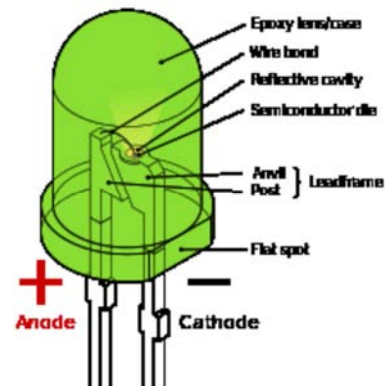


Figure 10. Light Emitting Diode.

3. Software Design Consideration

The software design for this project was implemented using a CCS C compiler for PIC microchip. This compiler consists of an optimized C compiler program as well as improved functions for many microcontroller operations. The flow chart on Figure 11 shows the implementation of the algorithm used in the programming of the microcontroller. The program on starting initializes the microcontroller unit on boot up. The controller then routinely circle round the to sensors polling the inputs for a brake in. if either motion or a break in switch is detected this initiates an action for the triggering of the GSM/GPRS module and an SMS or call is placed to the householder mobile phone while at the same time activating an alarm system.

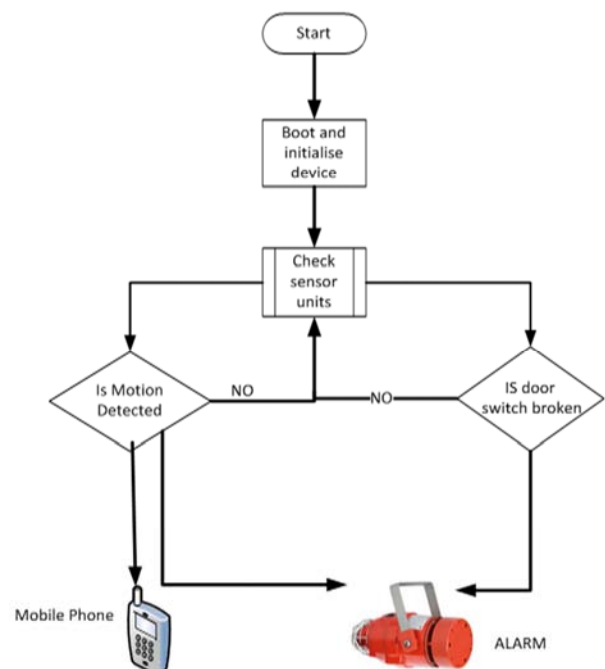


Figure 11. Showing the flow specialized type of modem chart for the program in the embedded processor.

4. Technology Considerations

The considerations for this system will include a choice of

networks, communication protocols and interfaces. Serial I/O is considered as options for connection between the GSM receiver and the microcontroller. The proposed system is designed to detect motion of either authorized or non-authorized persons around a house [10]. The system is designed with a GSM module, The GSM module system uses mobile network and is battery powered which makes home automation system safer from internet hacks.

5. Design and Validation

In this design an 8 bit PIC18F4520 microcontroller was used. The PIC18F4520 is a high-performance enhanced flash, microcontroller from Microchip with nano watt technology. The microcontroller also accepts input from switch sensors which can be placed on the hinges of doors or windows. Also included in the design is the PIR connector input for the motion sensor. The microcontroller is set to operate at 20MHz by the crystal oscillator and the paired 22pF capacitors. The program was run successfully.

5.1. PCB Implementation

The physical implementation of the design was carried out on the manufactured PCB boards for the two different system units namely the microcontroller and the GSM/GPRS module. The PCB was achieved through the tonner transfer method where the image of the PCB design is printed on a glossy paper and then transferred on a copper plated board by means of a heated surface on which pressure was applied. Etching of the board was achieved using concentrated Hydrochloric Acid and Hydrogen Peroxide. The components were then soldered into the respective component slots using a 30W soldering Iron [10]. Initial testing of the board was carried out using continuity meter to ensure all short circuit faults are properly cleared. Figure 12 showing the PCB diagram of the GSM/GPRS module and printed circuit board for the microcontroller unit of the proposed system.

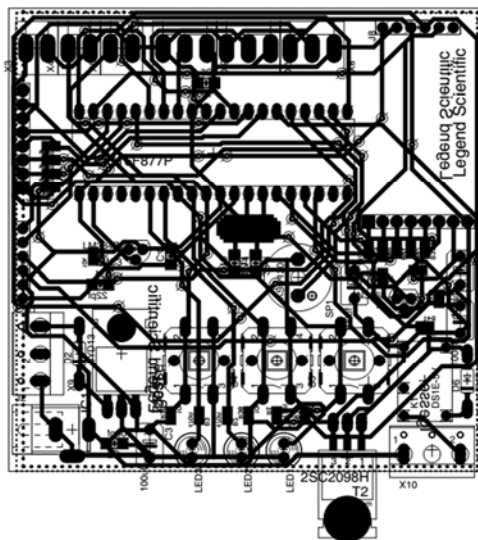


Figure 12. Showing the printed circuit board for the microcontroller unit of the system.

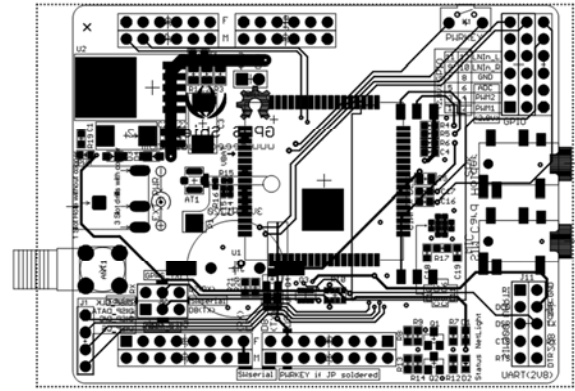


Figure 13. Showing the PCB diagram of the GSM/GPRS module.

5.2. Testing and Result

The testing instrument used for examining logical signal, testing and troubleshooting application in the course of this project were: digital multimeter, logic probe and oscilloscope. The test result shows that both the braking switches attached to the door hinges and the motion sensors perform adequately. The hardware system was properly tested because the software cannot work without the proper functioning of the hardware. The testing of the entire circuit was carried out in stages:

Each of the components was first tested using the multimeter in order to check for their state of performance and accurate values.

In the connection, each component on the PCB was then tested. This was done in order to carry out the continuity, which is meant for proper connection of the circuit and to detect any wrong connection.

The sensory unit circuitry was tested to ascertain the degree of sensitivity as expected.

5.3. Packaging

After proper testing was conducted, the packaging of the design into a model and casing was considered. The connecting wires were properly connected and well insulated; also the wires were well packed and bounded together.

6. Conclusion

The developed GSM based security system gives good response to the sensor and sends SMS when it detects intrusion at the windows or indoor. The test result shows that both the braking switches attached to the door hinges and the motion sensors perform adequately as expected. The entire decision making is done with a help of a PIC18F4520 microcontroller. The time taken by the system to deliver the SMS is dependent on the coverage area or range of the specified mobile network. A flexible way to control and explore the services of the mobile, AT commands is used in the system. In addition, the application of this design is in area of security usage, industrial use, commercial use, automation usage and remote indication.

7. Future Improvements

The future implications of the project are very great considering the amount of time and resources it saves. This system can be used as a reference or as a base for realizing a scheme to be implemented in other projects of greater level including audio-visual camera by sending the captured image to an e-mail instantly.

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