Microcontroller Based Remote Control Home Automation System for the Elderly and Physically Challenged using (HC-12) Module

Gachada B. Dubukumah, Mustapha Abubakar, Aliyu Buba Dahiru
Department of Electrical and Electronics Engineering, Modibbo Adama University, Yola
Department of Computer Engineering, Federal Polytechnic Mubi, Yola

Abstract—Home automation has proved over the years to be of incredible benefit for the elderly and physically challenge. Some of these elderly and physically challenged require assistance to meet important personal needs. The cost of living at home with monitoring devices and intelligent appliances is less expensive and more beneficial than attending medical centers or being supervised by nurses and employed care givers. This Project offers introduction and reviews on various Home automation systems, remote control, wireless data transceiver module, gas/smoke sensor, temperature sensor and the relevance of a microcontroller with an efficient software algorithm. A comprehensive set of detailed design and implementation of a home automation system for the elderly and physically challenge using a new generation multichannel embedded wireless transceiver module to remotely control the house lightings, power sockets and to monitor change in temperature and gas/smoke leakages and the buzzer to sound when the threshold is exceeded. The project employs a constructed remote control and an apartment with indoor/outdoor lighting points, power socket for electronic devices coupled with MQ2 gas/smoke sensor with a threshold of 1000PPM (Parts per Million) for the buzzer to sound, LM35 temperature sensor with a threshold of 50^{o}C for the buzzer to sound and interface with ATmega8 Microcontroller and HC-12 new generation multi-channel embedded wireless data transceiver module. The system can be expanded to implement renewable energy sources like home based solar system to enhance efficiency

Index Terms— Home Automation System, Remote Control, Microcontroller, Wireless Communication, Temperature Sensor and Gas/Smoke Sensor

1 INTRODUCTION

Home automation can be defined as implementation of technique which aid automatic operation of process or a system [1]. Home automation involves linking, monitoring or remote control of home appliances over intelligent network and systems. The intelligent network could be infrared, Bluetooth, GSM, Internet etc [1]. An automated home is known as "SMART HOME". The motivation is to facilitate users to automate their homes like turn on/off the lights, lock the front door or even turn down the heat etc, no matter the location of the user [2]. The application capabilities of home automation are quite vast; video surveillance, digital personal assistant integration, keyless entry, thermostat control, fire and carbon monoxide monitoring, remote lighting control, voice recognition, power plugs, home security systems etc [2].

Elderly people are vital and growing segment in the world population. The statistics show that the percentage of older people is continuously growing due to many reasons in particular, the reduction of birth rate and the decline of women fertility.

- *Engr Gachada B. Dubukumah is currently a Lecturer in the department of Electrical and Electronics Engineering, Modibbo Adama University Yola, Adamawa State, Nigeria. E-mail: g.dubukumah@mautech.edu.ng*
- *Co-Author 1,Mustapha Abubakar is a graduate from the department of Electrical and Electronics Engineering, Modibbo Adama University Yola, Adamawa State, Nigeria. Email: abkmustapha4@gmail.com*
- *Co-Author 2, Aliyu Buba Dahiru is a Lecturer in the department of Computer Engineering, Federal Polytechnic Mubi, Adamawa State, Nigeria. Email: 72moonali@gmail.com*

In the United States, the proportion of population 65 years and over has increase from 12.4% in 2000 to 13.3% in 2011 and it is projected to grow reach 21% of the population by 2040. The report also stated that 35% of people at age 65+ have some types of disability. Some of them require assistance to meet personal needs. Moreover, the current social life style, modern medicine, and the easy access to medical care have increase live expectancy. A United Nations report estimated that the life expectancy was 65 years in 1950 and 78 years in 2010 and it will continue to rise to 83 years in 2045 [1, 3].

In this project, a constructed remote control and an apartment with indoor/outdoor lighting points, power socket for electronic devices coupled with MQ2 gas/smoke sensor with a threshold of 1000PPM, LM35 temperature sensor with a threshold of 50^{o}C for the buzzer to sound once it exceeds the threshold, then an interface with ATmega8 Microcontroller and HC-12 new generation multi-channel embedded wireless data transceiver module is been proposed so that the control of home appliances can be achieved remotely.

The outcome of this project will enable the elderly people and the physically challenge to experience comfort of room temperature, convenience of switching indoor/outdoor lighting points, remote access from a remote controller, increase safety and components energy efficiency [2, 3, 4]. Figure 1 and figure 2 gives the block diagram of the construction. The block diagram presents a pictorial explanation of how each component is connected in the physical implementation.

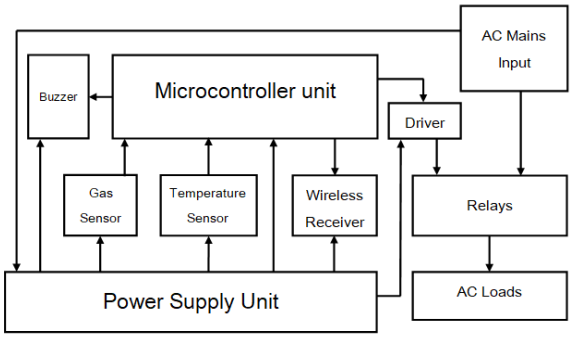

Figure 1: System Block Diagram with transmitter unit

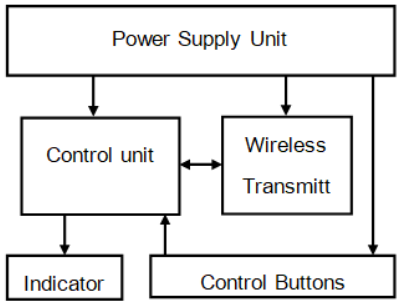

Figure 2: System Block Diagram with receiver unit

2 LITERATURE REVIEW

2.1 Remote Control

One of the earliest examples of remote control alert was developed in 1893 by Nikola Tesla. With the invention of relays earlier in 1835 by Joseph Henry it became possible to use remote controls to drive other devices by [5]. This is because of the ability or relays to serve as a switch that can control devices when energized by electricity. The first remote intended to control a television was developed by Zenith Radio Corporation in the early 1950's and made use of wire to connect to the television set. The remote unofficially called "Lazy Bones" used a wire to connect to the television set by [5].

Therefore the concept of remote control is further expanded in another form by applying it in a circuit that is used to power many appliances automatically by pressing buttons on the remote control. The elderly and physically challenge prefer simpler remote control using laser- engraved backlit buttons, some switches, and equipped with LCD screen to display necessary notifications. With the invention of Integrated Circuits like 555 timers and Microcontrollers, more functionality was added to whole concept of remote control alert by [5]. To each command buttons is associated a warning LED light that visualizes the situation status of the matching appliance. All operations are governed by microcontroller where the EEPROM (Electrical Erasable programmable read only memory) gives the opportunity to lock the remote by means of pass code stored in it memory [1]. The unique master board toggles the ON/OFF switches of the appliances by means of relays. The remote control and its base are communicating with RF signals realized by XBee transceivers [1].

2.2 Home Automation

In the year (2016), [6] design and development of voice activated intelligence system worked objectively to make the physically impaired or elderly people more self-dependent. This intelligent based system operates on voice commands. This implemented system consists of voice recognition and processing technology and wireless communication. This system is cost effective and efficient and it is also easy to implement. The proposed model works effectively with coverage up to 10 meters. The proposed system has some disadvantages, like people with speech impaired cannot use this system and the system is not highly noise resistant by [6].

Home automation system using brain computer interface (BCI) aimed to mainly concentrate on elderly people, sick patients and handicapped persons. The (BCI) Brain Computer Interface is one of the technologies where transmission takes place between human brain and external device. The proposed system is designed to control computer and hardware system using brain waves electric signals. It will detect the variations in electric signal strength through voltage level near the eye area and generates a wireless radio frequency signals to control the home automation prototype model by [7].

Internet of things (IoT) based home automation system is mostly called smart home automation system. The proposed system [8] is to cater for the physically challenged and the elderly people in their homes. The system use Raspberry Pi with wireless connection over Wi-Fi network to be controlled by smart devices like mobiles, laptops or desktops. These smart devices connected to the same Wi-Fi network can log into the GUI webpage entering the IP address of the Raspberry Pi and commands are sent to the receiver end. Actuators and sensors are connected to the Raspberry Pi to perform the necessary actions based on those received commands [8]. This system implies, the user must be very literate and be financially stable. Most of the elderly and physically challenge people experience low learning ability and lack enough funds.

2.3 Wireless data transceiver module

Most embedded systems communicate with other devices wirelessly. This wireless communication is often accomplished through optical communication or radio-frequency (RF) communication [9]. For many applications such as vehicle monitoring, remote control, wireless meter reading, radio tags reading, wireless alarm, biological signal acquisition, industrial data acquisition system, wireless data transceiver, digital home automation, fire and carbon monoxide monitoring, video surveillance etc, the medium of choice is RF.

Radio frequency has been used to substitute older infra-red communication designs as they do not require line-of-sight operation [9]. The transceiver module is a small Printed Circuit Board (PCB) sub-assembly that incorporates both a transmitter (capable of transmitting and modulating data radio wave) and receiver. Transceiver modules are usually employed together with a microcontroller (MCU) which will provide requirements for optimal transmission to the receiving point. The transceiver module circuits are typically designed for half-duplex operation, although a full-duplex module adds complexity to the design and are at a higher cost [9].

The requirements for home wireless communication technology are; low cost, low power consumption, ease-of-use, security, sufficient range, interoperability, scalability and sufficient network performance [10].

3 MATERIALS AND METHODS

3.1 HC-12 Wireless data transceiver module

The features of HC-12 are; a half-duplex 20dBm (100mW) transmitter paired with a receiver that has -117dBm ($2x10^{-15}$W) sensitivity at 5000bps wireless serial communication module with 100 channels in the 433.4 – 473.0 MHz range that is capable of transmitting up to 1000m in open space [11]. This project work employed the use of HC-12 new generation multichannel embedded wireless data transceiver module to transmit and receive serial information by connecting the HC-12 set pin, HC-12 RXD pin, HC-12 TXD pin to the ATmega8 MCU also connected a reservoir capacitor in parallel with HC-12 GND and Vcc pin.

3.2 ATmega8 Microcontroller

AVR Microcontroller is "Advanced Virtual RISC". The microcontroller used is ATmega8 ATMEL microcontroller. The features of ATmega8 MCU (microcontroller) includes sleep modes-6, inbuilt ADC (analog-to-digital), internal oscillator and serial data communication, performs the instructions in a single execution cycle [12, 13]. For this project work, 512 bytes of EEPROM, 8KB of flash program memory was enough for the software aspect, the devices has 28 pins of which 23 pins were programmed as input/out ports for interface with other devices (LM35, MQ2, HC-12 etc). Interrupt pins located on the device for external input, internal timers accessible for internal/external clocking and an inbuilt ADC (analog to digital converter) to alter the analog input signal into digital data of the 10-bit resolution. The SPI (serial peripheral interface) of the ATmega8 was used to implement the system communication.

3.3 MQ2 Gas/Smoke Sensor

MQ2 gas sensor is an electronic sensor used for sensing the concentration of gases in air such as methane, hydrogen, alcohol, LPG, propane, smoke, carbon monoxide and it has a low price and suitable for different applications. MQ2 is a metal oxide semiconductor type gas sensor. MQ2 gas sensor is also known as chemiresistor [14, 15]. This project work employed the use of MQ2 for gas/smoke sensor; it contained a sensing material whose resistance changes when it comes in contact with gas. This change in the value of resistance was used for the detection of gas. This concentration of gas was measured using a voltage divider network present in the sensor. This sensor works on 5V DC voltage. The sensing element of MQ2 has six connecting legs attached to it. Two legs were responsible for heating the sensing element; the other four were used for output signals. MQ2 was calibrated with a threshold of 1000PPM and configured using C-language, implemented through IDE.

3.4 LM-35 Temperature Sensor

Previous work on "digital room temperature meter", showed how LM35 temperature sensor coupled with a microcontroller aided the technology advancement of a digital thermometer [16, 17]. This project work employed the use of LM35 temperature sensor because it is a low-power, low-cost, high-precision, measure both body temperature of an object and ambient temperature, easy-to-use and does not require external component to calibrate the circuit. The operating voltage 5V and 60uA current were used in this project which made it perfect for battery-powered application. Using the basic principle of a diode to measure known temperature value, the LM35 temperature sensor was set at a threshold of 50^{o}C to monitor and sound an alarm.

3.5 Buzzer

The buzzer or alarm is a sounding device that can convert audio signals into sound signals within the range of 2 to 4 KHz. It is usually powered by DC voltage and used in timers, alarms, devices, printers, computers etc [18]. This project employed the use of a buzzer to achieve alertness and efficiency of the system. This buzzer consists of piezo crystals between two conductors. When energy was applied across these crystals, they push on one conductor and pull on the other. This, push and pull action, resulted in a sound wave.

3.6 Relay Module

The four-channel relay module can be used to control various appliances and equipment with large current and also interface to a microcontroller and sensor easy with minimum devices and connections [19]. This four-channel relay module used in this project has four 5V relays and the associated switching and isolating components made it easy to interface with a microcontroller. The contacts on each relay are specified for 250VAC and 30VDC and 10A as marked on the body of the relays. The four relays on the module are rated for 5V once an approximately 5V appears across the coil, the relay is activated.

3.7 Indicator Lights

Indicator lights are type of illuminating device that is commonly used to signify that equipment is either receiving power or that there is some form of malfunction [20]. The project employed the LED (light emitting diode) as power ON/OFF indictors on the system also served as indoor and outdoor lighting points.

3.8 Clock Oscillator

The standard clock oscillator is the most common type of oscillator used and has applications in virtually every aspect of the electronics industry. Most programmable components have manufacturers operating frequency given in the component's datasheet; it can also be coupled to the component [21]. A clock oscillator was used to establish a reference frequency for timing purposes.. A quartz crystal rated 8MHz was used for the ATmega8 microcontroller in this project.

3.9 Power Supply

The power supply section supplies the required power to the various parts of the system. The receiver side (house/apartment side) functions based on a 220VAC power supply and 9V battery, the 220VAC power the lighting point and power plug. Then the 220VAC is then step down to 9VAC using step down transformer, the 9VAC is then converted to DC using rectifier. Then a filter capacitor filters the ripples and 7805 regulator step it down to 5VDC. The 5VDC was then filtered again before supplying to various part of the system. The sensors and the buzzer are powered by a 9V Battery in the case of power outage. The transmitter side (remote side) functions base on 9VDC battery. The 7805 regulator regulates it to 5VDC. Then the capacitor filters the ripples and 5VDC was supplied to the various components of the remote system.

4 SYSTEM DESIGN

4.1 System Description

This section describes how the hardware design was developed by coupling together the physical components from the systems block diagram shown in figure 1 and figure 2. The software design was developed from interpreting the system flow chart that controls the hardware components of the system with an efficient software algorithm using C-language.

This project enables the elderly and physically challenge to use the microcontroller based remote control coupled with HC-12 wireless transceiver module to turn ON/OFF the apartment indoor and outdoor lighting points, turn ON/OFF the 13A power socket and monitor the apartment temperature and gas or smoke presence/leakage. The system was also programmed to make the buzzer sound once the MQ2 sensor senses smoke/gas above threshold of 1000PPM and also the buzzer make sound when there's increase in temperature above 50°C. All the components used in this project have low power consumption, portable and low cost embedded control system which is compatible for home automation and remote monitoring. Furthermore the circuit diagram was designed using a PROTEUS professional circuit designer.

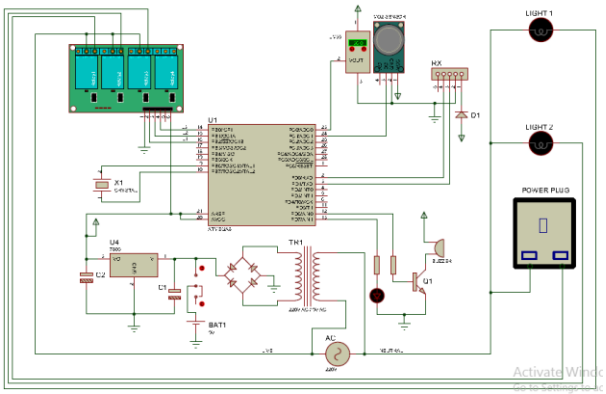

Figure 3: Circuit Diagram with Receiver unit

4.2 Components connection to the ATmega8 microcontroller

The experimental devices or the components are coupled to the control circuit (microcontroller). The pins of the Atmega8 microcontroller support two signals except 5-pins (pin-7: VCC, pin-8: GND, pin-22: GND, pin-21: AREF and pin-20: AVCC). The Atmega8 microcontroller consists of 28 pins where pins 23,24,25,26,27,28 and 1 are used for port C, pins 2,3,4,5,6,11,12 are used for port D and pins 9,10,14,15,16,17,18,19 are used for port B.

The LM35 temperature sensor is a non-contact temperature sensor, it is connected to pin-23 of the ATmega8 microcontroller which is used for ADC (digital value of analog input) channels.

The MQ2 gas/smoke sensor is connected to pin-24 ATmega8 microcontroller which is used for ADC (digital value of analog input) channels.

The HC-12 transceiver module, the RXD & TXD pins are connected to pin-3 and pin-2 respectively. The pin-2 and pin3 are used in universal synchronous and asynchronous receiver transmitter (USART) for serial communication.

The 4-channel relay interface board allows the control of various appliances and other equipments with large current. Pin-2 of the relay module is connected to pin-16 of the microcontroller, pin-3 of the relay module is connected to pin-15 of microcontroller and pin-4 of the relay module is connected to pin-14 of the microcontroller.

Terminals 1 and 2 of the 8MHz crystal oscillator are connected to pin-10 and pin-9 of the microcontroller respectively. Pin-9 & pin-10 are used as a timer counters oscillators as well as an external oscillator where the crystal is associated directly with the two pins.

Pin-10 is used for low-frequency crystal oscillator or crystal

oscillator. If the internal adjusted RC oscillator is used as the CLK source & the asynchronous timer is allowed, these pins can be utilized as a timer oscillator pin.

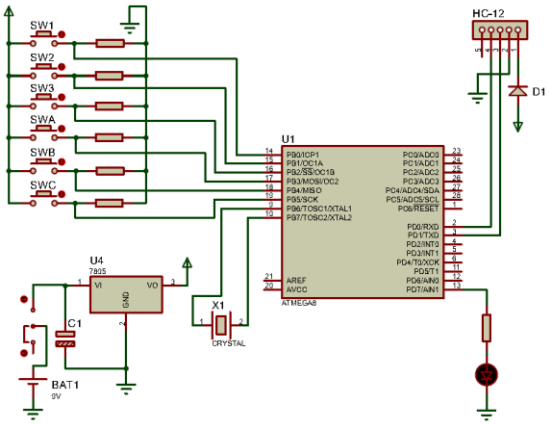

Figure 4: Circuit Diagram with Transmitter Unit

4.3 System Software Development

An integrated development environment (IDE) is a software application that provides comprehensive facilities to computer programmers for software development. An IDE normally consists of a source code editor, build automation tools, and a debugger. Most modern IDEs have intelligent code completion. Some IDEs contain a compiler, interpreter, or both. The software program was developed using a suitable integrated development environment (MikroC Pro IDE) as shown in figure 5 below.

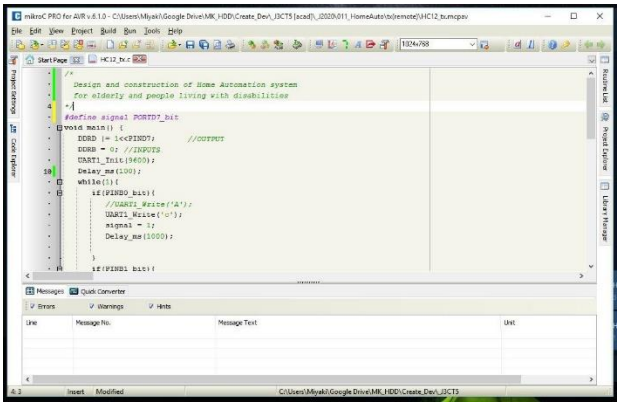

Figure 5: MikroC Pro IDE

4.4 System Flow-Chart

Microsoft office Visio was used to design the system flow charts both for the transmitter and receiver units. The entire system, the MCU and the HC-12 are initialized then after the sensors are set to read and compare the captured values and the reference values before it sounds the alarm/buzzer. The setting ON and OFF of light 1 (indoor), light 2 (outdoor) and the power socket awaits the command prompt from the user.

All these shows a complete analysis of the system design from the software C-code developed and the system design flow chart.

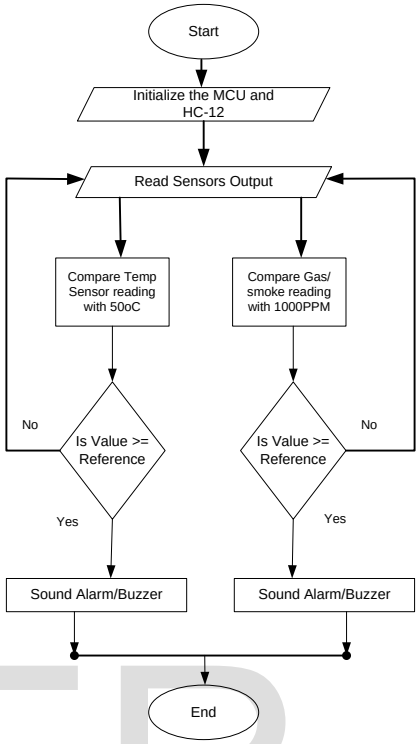

Figure 6: Transmitter Flow Chart

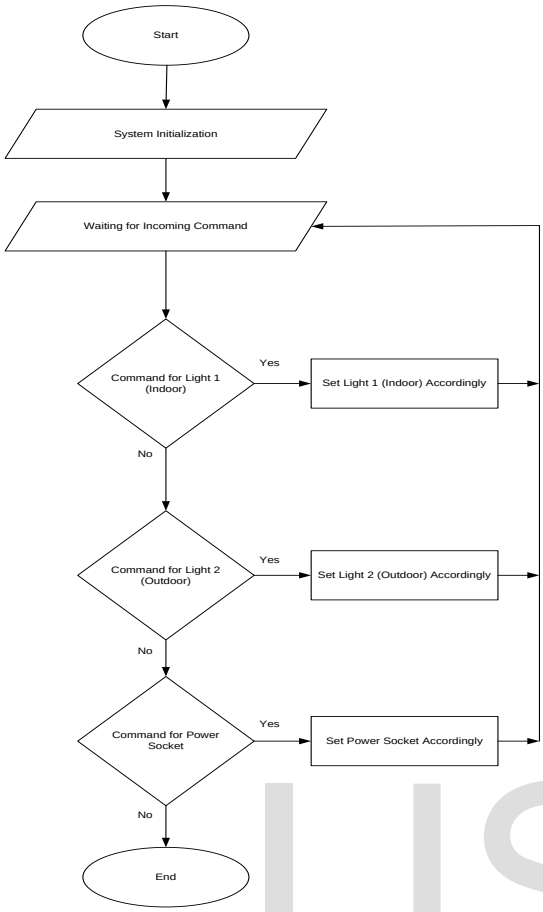

Figure 7: Receiver Flow Chart

5 IMPLEMENTATION AND RESULTS

5.1 Implementation on Printed Circuit Board

In this section, all manuscript works that pillared the project design were made handy by physically incorporating the hardware and software component of the design. Initially, the project was implemented on a solder less board to validate its workability and to ease adjustments then the project construction was transferred to a printed circuit board (PCB). The PCB was designed using a PROTEUS professional circuit designer. The circuit was designed using the schematic editor, and the PCB was then designed using the ARES part of the software. The designed PCB was printed on a glossy paper and transferred to the copper plated board using a heat transfer method as seen in figure 8 and figure 9. Etching is the process of removing the unwanted part of the copper. The etching was carried out using ban etchant. The etchant used in the process is a mixture of diluted hydrochloric acid and a hydrogen peroxide. A 30% of hydrochloric acid is diluted in a 70% of distilled water and the acid is mixed in a 50% of hydrogen peroxide. After the etching, the board was cleaned using a cleaning agent to remove the carbon particles off the board surface.

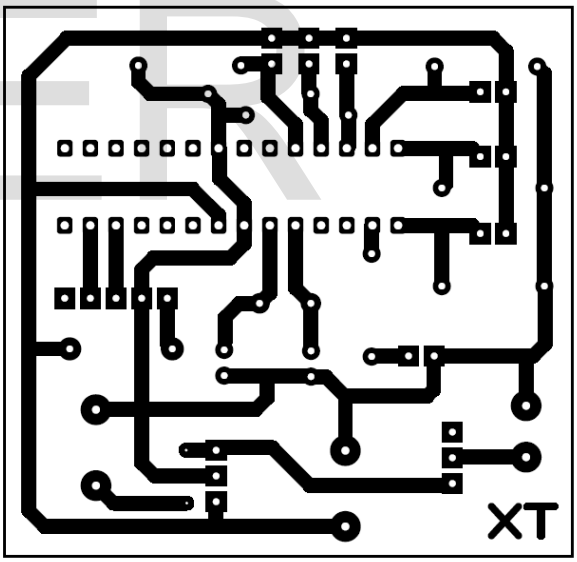

Figure 8: Transmitter Unit on PCB

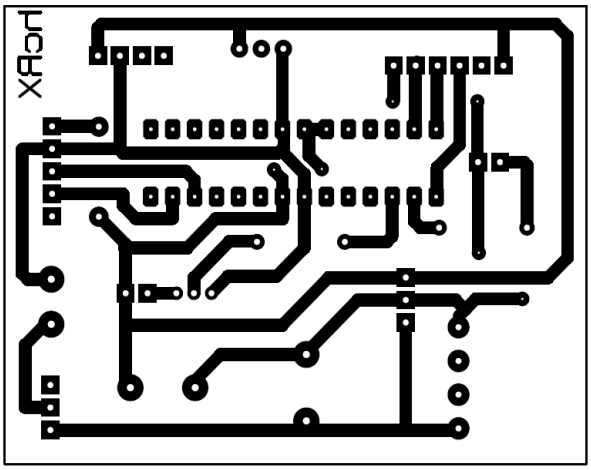

Figure 9: Receiver Unit on PCB

5.2 Result and Discussion

First the components were tested to determine the operating characteristics of the components and comparing it to the datasheets of the components. The various components tested include the HC-12 module, LM35 temperature sensor, MQ2 gas/smoke sensor, the capacitors, the resistors, diodes, the relays and other minor components. The modules were coupled together to the microcontroller as per design and a software algorithm was developed using C-language to control the designed operation. The minor components were measured using a digital multimeter. The values obtained were compared to the specified values of the components. The major equipments used in the component testing are the digital multimeter and the Arduino Uno board. This section was also done in stages based on the system block diagram to avoid complexity in troubleshooting any abnormality when the whole project reaches completion.

The outcome or performance of the project work can be seen in figure 10 to 15 and it worked perfectly.

5.2.1 Apartment at Power ON

The apartment is made up of indoor light, outdoor light, power socket (which serves as source of power to electrical loads such as TV sets, and other electronics devices), gas sensor and temperature sensors. All these were tested and work perfectly. As shown in the figure below 10.

Figure 10: The constructed apartment when Power ON

5.2.2 Apartment at Power OFF

When there is power outage in the apartment only temperature and Gas sensors work using 9V DC battery source. The advantage of introducing DC power to the system is because the sensors are DC loads. The figure 11 below shows the apartment when there is power outage.

Figure 11: The constructed apartment when Power OFF

5.2.3 System Remote Control

The system remote control is portable and easy to operate which makes it user friendly. The system was operated using the remote at distance of 50m, it was extended to greater than 50m at open space round the apartment. As seen in figure 12.

Figure 12: Workable remote control at a distance

5.2.4 Test for Gas/Smoke

Burnt paper was brought close to the gas/smoke sensor and the buzzer was turn ON. The figure 13 below shows the burnt paper brought close the gas/smoke sensor, immediately the buzzer is ON to alert the user.

Figure 13: Gas/Smoke detection

5.2.5 Test for change in Temperature

The temperature sensor senses any heat temperature above 50 Degree Celsius. The test was carried out by bringing hot iron close to the temperature sensor as shown in figure 14, immediately the buzzer is ON to alert the user.

Figure 14: Temperature change

5.2.6 Power Socket

The 13A socket in the system was tested by charging a mobile phone as shown in the figure 15.

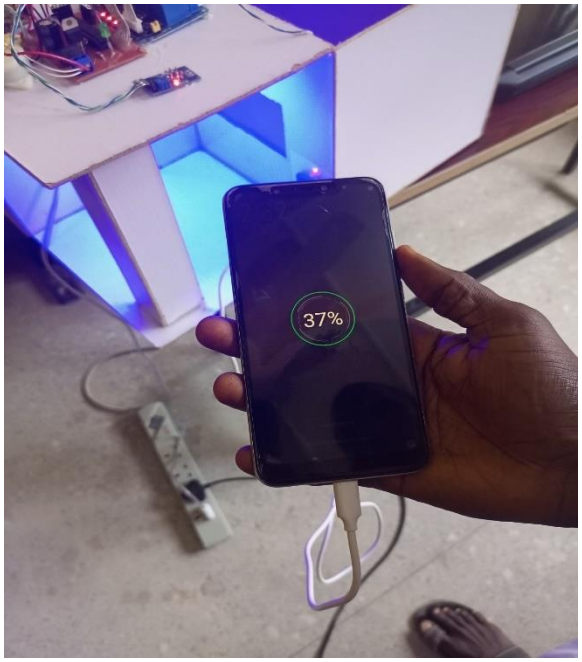

Figure 15: Power Socket display

5.2.6 Comparison of contact distance of gas and corresponding resistance with MQ2 sensor values

The MQ2 gas sensor is also known as chemiresistor and it contains a sensing material whose resistance changes when it comes in contact with gas. This change in the value of resistance was used to compare the MQ2 readings on bread board and PCB as shown in Table 1.

Table 1: Comparison of contact distance of gas and corresponding resistance with MQ2 sensor values

The table 1 below shows the good sensitivity of the MQ2 sensor on printed circuit board (PCB) in close contact with gas or smoke within the premises.

Contact distance of gas (cm)	Resistance (ohms)	MQ2 on bread board (PPM)	MQ2 on PCB (PPM)	Variations
5	2	998	1000	2
10	3	995	998	3
15	4	991	995	4
20	5	987	991	4
25	6	985	989	4
30	7	980	985	5

The MQ2 sensor for gas/ smoke and the LM35 sensor for temperature tend to more precise and reliable when operating on the printed circuit board (PCB). For the LM35 sensor, as the surrounding temperature increases it takes some time-minutes (uses the basic principle of a diode) to reach the threshold of 50^{o}C to sound the buzzer/alarm.

6 CONCLUSION

The design and implementation of a microcontroller based remote control home automation system for elderly and physically challenged using HC-12 module was achieved based on the system's ability to enable the user have access and control of the apartment indoor and outdoor lighting points, 13A power socket, apartment temperature and monitor gas or smoke presence/leakage. From the system design, an efficient software algorithm in C-language was developed using MikroC Pro IDE to operate the ATmega8 microcontroller coupled with HC-12 wireless data transceiver module (for transmitting and receiving signals) that has activated proper functioning of the MQ2 gas/smoke sensor to detect any leakage of gas or presense of smoke above threshold of 1000PPM to alert the user by a buzzer and LM35 temperature sensor to also alert the user whenever there a rise in temperature above 50^{o}C. Also the work developed a remote control to turn ON/OFF of the LEDs for the apartment lighting points and the 13A power sockets.

7 RECOMMENDATION

The system can be expanded to implement renewable energy sources like home based solar system to enhance efficiency. Also to improve the transmitter-receiver designs for wider communication coverage between the remote control and the home automation system gadgets. In addition, the design can be improved by incorporating it to the power distribution panel of buildings so that it will be able to automatically trip off power supply to the building when there is any threat.

8 ACKNOWLEDGMENT

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