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Implementation of a GSM phone-controlled door using a microcontroller

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Abstract
Provision of adequate security system in Nigeria has become one of the major challenges due to the level of insurgency that is increasing at an alarming rate in the country. The need for protection of life and properties therefore requires additional security measures. In this study, we designed and implemented a GSM phone-controlled door using microcontroller. The design was achieved by the use of GSM technology, Atmega 2560 microcontroller, GSM Module, and a keypad. The Microcontroller was programmed using Arduino C language and simulated using Proteus 8.1. The door can be remotely controlled by receiving set of instructions either through the GSM phone or the keypad acting as the transmitter. The modules are made possible using modern integrated circuit chips, ensuring proper conversion of signals to acceptable codes, enabling the microcontroller to communicate properly with the switching device responsible for opening and closing the door. Results show that, the microcontroller accepts input from the keypad in form of password, process it and grants access if the password is correct, or deny access if the password is wrong. However, if a wrong code is sent over three consecutive times; the password will have to be reset, because the system has sensed an intruder attempt. The device can be recommended for use in our homes, offices, business places etc. ensuring a good security system.

Keywords: GSM phone, keypad, microcontroller, proteus, security door, simulation

1. Introduction

The role of information communication technology in our Morden day cannot be overemphasized. Unlike some time ago where item such as mobile phones were so expensive and as a result only a few could afford it, but it is relatively cheap now with lots of options in terms of brands and networks. Mobile communication system is an essential entity that provides the ability to disseminate Information to a far distance depending on the coverage area and capacity of the network [1]. Based on the features that mobile communication provides, Bamisaye *et al*. [1] explained that it has been of great advantage in business, security, banks, companies, and institutions. Security has been a prime concern to both individuals and governments.

Insecurity is the state of being open to danger or threat; lack of protection [2]. The subject of security is therefore of outmost necessity in our daily life activities. According to Femi [2], security entails the measures, facilities and systems put in place to secure citizens and resources from danger and the risk of infiltration. In line with this, Eso [3] had explained that security is freedom from physical hurt, human right abuse or other treats to what constitute the core of individual security. Progress cannot be achieved or sustain without reliable security system in place. Security system plays important role to prevent unknown user entry access into a secured place without being authorized [2]. The concern here is for both the physical property and the intellectual property. Nowadays, security has been the prime concern in the home and office management. Despite the various methods proposed to provide security in our present-day society including, huge financial budgeting, recruitment and training of personals, purchase of arms and vehicles for security personnel etc. the system is yet vulnerable.

Automatic doors replace the customary security frameworks which utilizes key to open entryway by use of keyless passage to the entryway [4]. Door security system is divided into two types; the normal door lock system which uses manual means to access the premises and the use of electronic automatic identification system which is a little more confiscated means. In general, locks are very simple devices that are employed to address a straight forward problem. Lock can be easily hacked by unwanted people thereby allowing unauthorized people into the secured premises [4]. Ojo *et al*. [5] emphasized that, digital door lock security system provides security and safety to house or office owners, belongings, assets from being damaged by external agent or unwanted strangers. They are doors to keep people out; key locks and chains reinforce the mode of security. Doors are being made of metals not just wood alone anymore. Security challenges such as cybercrimes, hackers, kidnapping, herdsmen, smugglers, armed robbery, terrorism and lots more are on the increase in Nigeria and globally. This calls for the need to implement systems that can guarantee adequate security. Influential people in the society have bulletproof doors to ensure the security of self and others. This has brought about the reliability of already existing systems and look into the possibility of creating systems that are smarter and more secured. Home security for instance improves the quality of the resident's life by facilitating a flexible, comfortable and secure environment [6]. Hassan [7] stated that, nowadays-embedded system is designed to produce security due to tremendous improvement in microcontroller unit and wide spread of Global System for Mobile Communication (GSM) technology. Adequate security has been a prime concern in the home and office management. In literatures, research suggested a number of security system based on new technologies like, General Packet Radio Service (GPRS), Internet, Ubiquitous Sensor Network (USN) and implementation through Field Programmable Gate Arrays (FPGA), Application

Specification Integrated Circuit (ASICs), Digital Signal Processing (DSP) and Microcontroller Unit (MCU) [8]. Mobile phones have built-in GSM module, which enables them to connect with any cellular network in the globe. In certain applications, the microcontroller-based system has to be connected with the GSM network that will enable a user to control the system by sending messages or making a call [8, 19]. Though, some had no provision for SMS in case of operation failure [13] and some lack the ability to alert the user of security treat or an intruder via SMS [15]. The systems that can send messages to user to alert or inform about the status of the system running may use a separate GSM module rather than using that of the mobile phones [9].

Furthermore, devices such as motion detectors, light detectors among others are susceptible to be triggered by false signals such as noise impulses, whenever its sensitivity is increased. They are not suitable for most outdoor security protection because they do not possess high discriminative capability during operation and they are expensive**.** Most recent of these devices are offshoots of biometric engineering. The major characteristic of security devices is to prevent an intruder from gaining access to a location [20]. Folanya [21] further stressed that, most of these devices however have lapses which give an unauthorized person access to where they are barred. For instance, the simple jam lock and pad lock can be forced open or the keys duplicated by unauthorized persons and under certain conditions, i.e. physical changes of the individual concerned. The mobile phone-controlled door lock security system technology is an access control system that allows only authorized persons to access restricted area [22].

The aim of this study is to design and implemented a GSM phone-controlled door using microcontroller and matrix keypad which serves as an alternative. The Microcontroller is programmed using Arduino C language and simulated using Proteus 8.1. The door can be remotely controlled by receiving set of instructions either from the GSM phone through Short Message Service (SMS) effectively from the authorised GSM or the keypad which serves as an alternative by entering a registered password. A buzzer that forms the alarm system and an LCD that displays the result of the processing are incorporated to the system.

This research will be beneficial to people in terms of its affordability, security guaranteed, safety of lives and properties, independence to mains power gride (solar powered) and access control of people to restricted areas. People in regions with access to GSM technology will benefit more from this research. The system is subscriber friendly; any network can access it. Also, it is not limited to particular made or make of phones as long as the phone does the basics. Security door is always important in places like airports, hotels, supermarkets, theatres, banks, individual homes and restricted premises. The research will give individuals and organisations the opportunity to provide security for themselves at an affordable price not having to wait on the government. In addition, challenges such as misplacement of keys will also be minimized.

2. Materials and Methods

2.1 Materials

For the design and simulation of a GSM phone-controlled door, some of the major materials used include, ATMega2560 microcontroller, LM7805 Voltage regulator, SIM900D GSM Module, 4x4 membrane keypad, BC327 NPN transistor, Proteus 8.1 software, 16x2 LCD display, PC windows 8.1 computer, 5V 1-channel relay, 9V 2500mAh battery, and assorted resistors.

2.2 Methods

The ATMega2560 microcontroller on Arduino Mega board was chosen for this research because of its unique features which includes low cost, and provision of highly flexible and cheap solution to most embedded control applications. The method was a step by step simulation and implementation following the block diagram in Fig. 1.

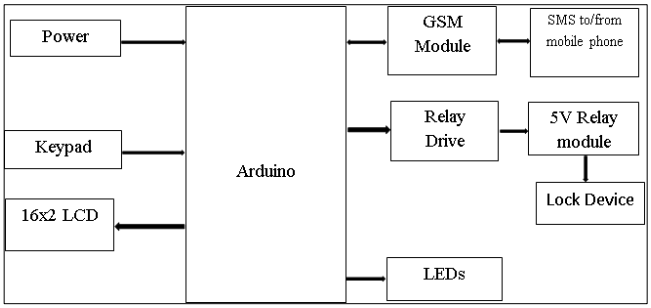

Fig 1: General block diagram for the system

From the diagram, we can classify the system into three sections; these are input, controller and output sections. At first, the controller section remains at waiting state for receiving a signal from input section which includes a 4 x 4 keypad, mobile phone, and the LCD display. In the input section, a mobile phone through its device will be used for interfacing with microcontroller to lock or unlock the door of the system. Consequently, a manual keypad performs the similar function. In accordance with the input devices; the controller section takes decision and activates the output section which includes the, GSM module, LED and Lock device. However, the activation of the output device depends on the activity of the input section that indicates user to lock or unlock the system. The Arduino board with Atmega 2560 is shown in Fig. 2.

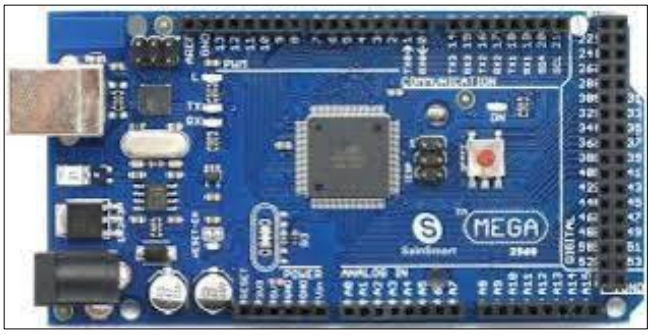

Fig 2: Arduino board with Atmega 2560.

The Arduino Mega has a total of 54 digital I/O pins of which 15 provide PWM output and 16 are analog inputs, 4UARTs (hardware serial ports). The digital pins can be used as either inputs or outputs. The board has a 16 MHz ceramic resonator, a USB connection and a power jack. The Arduino board has a number of pin ports which serve as a connection points. Some selected pins are presented in Table 1.

Table 1: Selected pins on Arduino

Pin	Connection
D0 (RX0)	TXD Console
D1 (TX0)	RXD Console
D2	GSM TXD
D3	LED Busy (D1)
D4	LED Success (D2)
D5	GSM RXD
D6	Relay module
D7	Keypad D column
D8	Keypad C column
D9	Keypad B column
D10	Keypad A column
D11	Keypad 3 column
D12	Keypad 2 column
D13	Keypad 1 column
A0	RS pin on LCD
A1	E pin on LCD
A2	D4 pin on LCD
A3	D5 pin on LCD
A4	D6 pin on LCD
A5	D7 pin on LCD

The keypad module is attached to the digital pins 7 – 13 on the Arduino board where password is received or entered. This 16-button keypad provides a useful human interface component for the microcontroller is as shown in Fig. 3. Matrix keypad uses a combination of four rows and four columns to provide button states to the host device. Underneath each key is a pushbutton, with one end connected to one row, and the other end connected to one column. In order for the microcontroller to determine which button is pressed, it first needs to pull each of the four columns (pins 1-4) either low or high one at a time, and then poll the states of the four rows (pins 5-8). Depending on the states of the columns, the microcontroller can tell which button is pressed.

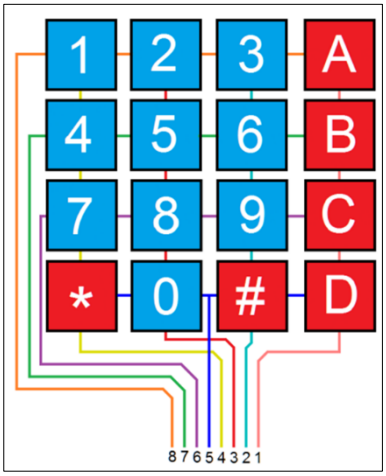

Fig 3: Matrix Keypad Connections

The flowchart for a GSM phone-controlled door system using a microcontroller begins with a start, followed by the initialization of the variables. On booting the system, during its setup, the busy LED on pin D3 will lit up and after the system setup it will switch off. The system will prompt the user through LCD screen to enter password via the keypad.

On entering the password, if it is successful; the success LED on pin D4 will lit up and the door will unlock which is shown by the switching of the relay and the LED connected to it. If the password is wrong, the user is prompted to enter it again while the attempts will be incremented and if the attempts equals to three, an SMS alert is sent to the owner and also the lock/door is freeze. The door can only be unlocked by sending the right command to unfreeze. The flowchart of the system can be shown in Fig. 4.

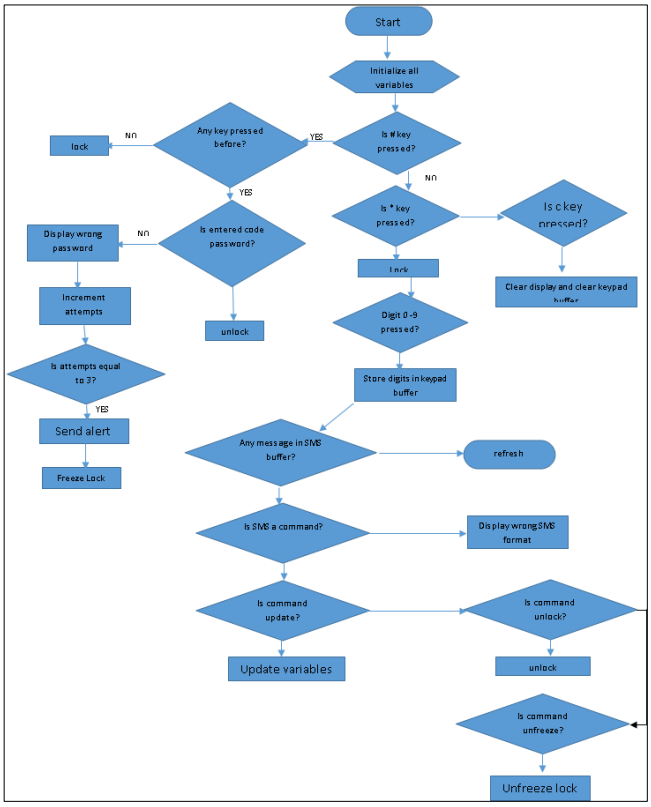

Fig 4: System flow chart

3. Results

3.1 Simulation Results

The system was implemented in Proteus 8.1 environment and results were obtained in various stages to ascertain the functionally. Results obtained are presented in Figures 5 to 10 respectively.

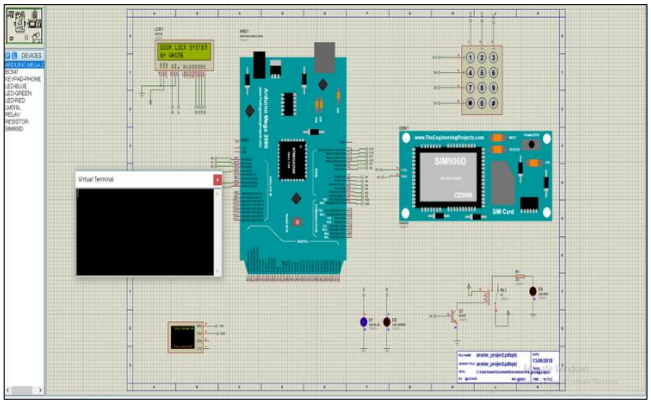

Fig 5: Simulation result for system initialising

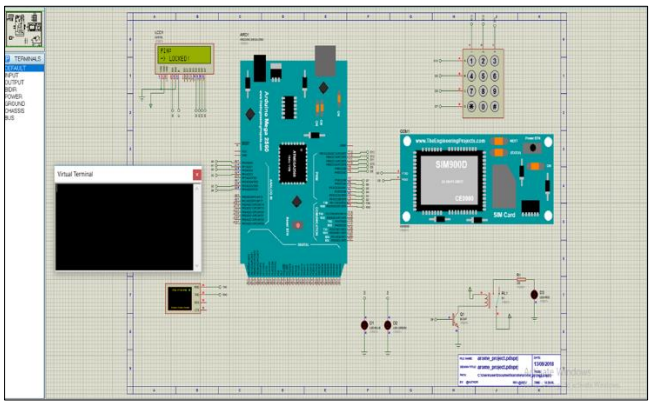

Fig 6: Simulation result for system locked ready to accept the next command

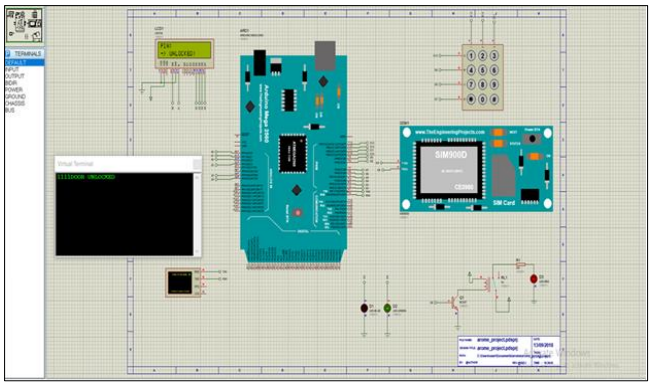

Fig 7: Simulation result for system unlocked using the right pasword

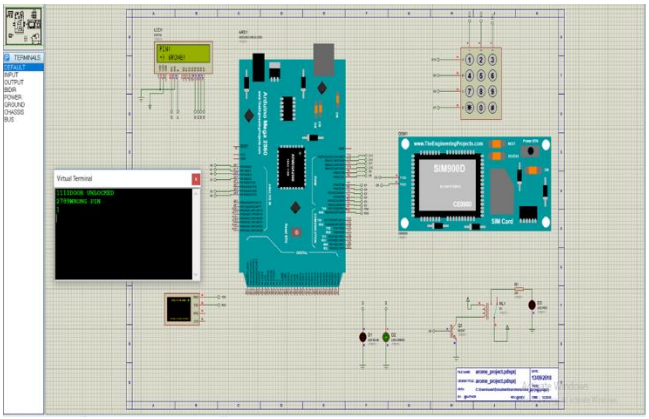

Fig 8: Simulation result for system response with the wrong password

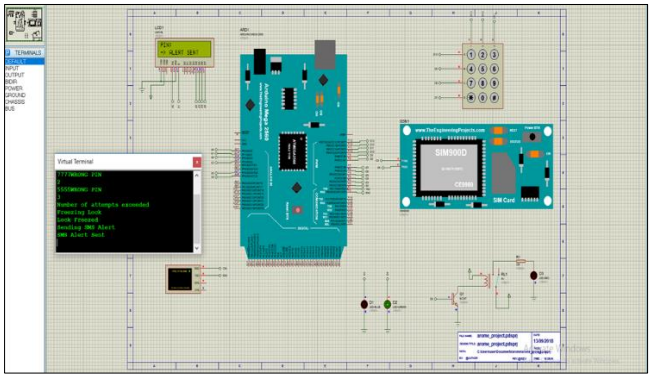

Fig 9: Simulation result for maximum attempts exceeded, lock frozen and sending alert

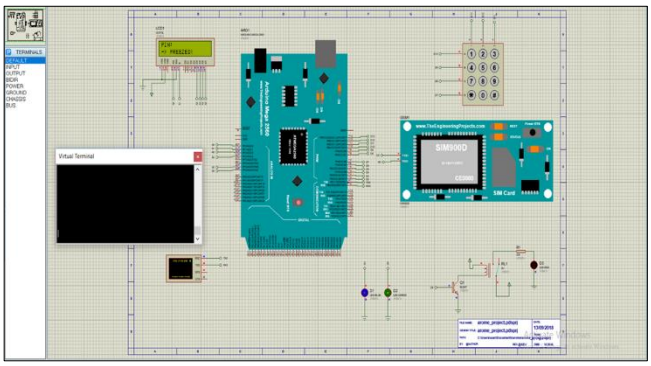

Fig 10: Simulation result for system frozen after maximum attempts

Fig. 5 shows the system in initializing stage with the display of the system status shown on the LCD as "DOOR LOCK SYSTEM BY AROME". The colour of LED D1 changes from blue to black to indicate that it has completed its initialisation process and set to receive the Pin. Fig. 6 presents the next stage where the system displays "LOCKED!" At this stage, the password can now be accepted to unlock the system and the keypad serves this purpose. The # (hash) button is used to unlock the system after the password while the * button is used to lock it back after the operation. Fig. 7 shows after the Pin was entered and the system displays "UNLOCKED!" on the LCD. The digit 1111 is programmed as the acceptable password. Any other entry is seen as an intrusion in the system. The colour of D2 LED changed from black to green which is an indication that the password is correct. Also, the relay turns from the locked position at R1 closer to the transformer to indicate that the door is now open. This will however remain unlocked until the *button is entered.

Fig. 8 shows when a wrong password was entered after the door was locked, the system displays "WRONG!" on the LCD which indicates that the door remains lock. Also, the colour on D2 remains Red and the relay also remains in its unlocked position. Fig. 9 shows several attempts of different passwords used as attempt to unlock the door with three attempts made the system displays "ALERT SEND!" The system sends an alert to the user informing the presence of an intruder and freeze as shown in the visual terminal. At this point it can only be unfreeze by the owner. Fig. 10 shows after maximum attempts, the system display "FREEZED!" At this stage the system will not accept any more command except the unfreeze GSM command/code. Alternatively, the system can be unfreezed using a code typed in from the keypad.

3.2 Theory and Calculations

From Ohms law, the size (in ohms) of the protection resistor to be interfaced with the LEDs that will serve as current limiting device which protects from over or under current, can be given by equation (1) as:

$$R_{min} = \frac{V_{CC} - V_{drop}}{I_{LED}} \quad (1)$$

where V_{CC}= 5Volts

I_{LED}= LED current (20mA)

R_{min}= minimum required resistance value

V_{drop}= Voltage drop across LED (selected LEDs has 2volts)

Therefore,

$R_{min} = \frac{(5-2)volts}{20mA} = 150\boldsymbol{\Omega}$

To achieve current limitation, a resistance value higher than the calculated $R_{min}$was selected. A 220Ω resistor was used and thus only 13.6mA current was allowed to pass through each of the three LEDs.

To protect the microcontroller from back EMF, during switching, a diode was connected across the relay. A resistor of 470Ω was selected and thus the current through the transistor was limited using equation (2) as:

$$I_{lim} = \frac{V}{R} \quad (2)$$

$$I_{lim} = \frac{4.3V}{470\Omega} = 9.12\,mA$$

Using solar panel as backup power, the charging current can be calculated using equation (3) as:

$$charing\ current = \frac{solar\ panel\ power\ (watts)}{voltage\ rating} \quad (3)$$

Therefore,

$$charging\ current = \frac{4.5watts}{6volts} = 0.75A$$

In calculating the charging time, we use Equation (4) as:

$$charging\ time = \frac{battery\ capacity\ (AH)}{Charging\ current} \quad (4)$$

where, battery capacity (Ah) = 1800mAh Charging current = current from the solar panel module

$$charging\ time = \frac{(1800/1000)}{0.75} = 2.4hrs$$

To calculate the discharge time of the battery; we use Equation (5) as:

$$discharge\ time = \frac{battery\ capacity\ (Ah)}{Load\ (Ah)} \quad (5)$$

where, battery capacity (Ah) = 1800mAh

Load = 200mA (Maximum current Arduino mega board can draw)

Therefore,

$Discharge\ time = \frac{1800mAh}{200mA} = 9hrs$ (This is a huge advantage)

4. Discussion

The implemented circuit of the GSM phone-controlled door working sequence has proved the effectiveness of the device in terms of door security. The alert sending system which informs the presence of an intruder can be of great importance to the user so as to take various precautionary measures especially in situations when the user is not at home. There is no need to keep keys for particular lock since the locking technique is unique with GSM based authentication. All the modules worked perfectly well showing the effectiveness of the algorithm used and the programming accuracy. The circuit design is similar to the work of [4, 9, 12, 14]. But different from that of [13] that had no provision for SMS in case of operation failure and [15] that lack the ability to alert the user of security treat or an intruder via SMS.

5. Conclusion

The design and simulation of GSM phone-controlled door provides solution to the security challenges in secured premises by granting authorized person's access or denying unauthorized person's access. The system is intelligent enough to monitor the secured environment. Atmega2560 microcontroller on Arduino platform was used as the control unit in this work. The program was written in C language which is more effective in developing embedded technology compared to other programming languages. In this research, LED lights and LCD are the promising features used to ensure reliability. However, a finger print module can be integrated into the circuit in order to increase the efficiency. A voice feedback can be an added advantage of the system and operating the door lock security system by face detection method will be much more secured. Also, burglar alarm module can be introduced to circuit to trigger the activity of an intruder within the premises. In addition, a Bluetooth device will be of great advantage if interfaced with the microcontroller to serve as another signal input device for the system.

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