



Design and Implementation of a Mobile Phone Controlled Door Lock System

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ABSTRACT

Mobile phones network finds wide use in today's world, this makes them, suitable for remote automation and control. In this paper, a mobile phone-controlled door lock system was designed and implemented. The designed system uses a microcontroller and GSM module, to control the door operation. The control codes used by the microcontroller were developed in Arduino IDE (Independent Development Environment) using Arduino language. The prototype of the system was developed using a servomotor as an actuator for the door lock system. The GSM module was used as a link between the microcontroller and the door lock system to be controlled. It receives the command from a remote mobile phone and sends the command to the microcontroller for required action to be taken. The commands are in the form of a phone call with code authentication. The system has a door status information capability which can obtain via SMS.

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INTRODUCTION

Common in today's world are services providing systems using portable devices. Technologies are used in homes and buildings in other to secure them, for personal safety and reduce human efforts. Fast-moving life technologies that reduce human effort and save time is very much welcome. GSM. The Global System of Mobile Communication is the most popular cell phone standard and is used internationally. GSM is an open and digital cellular technology used for transmitting mobile voice and data services, it operates at the Quad-band [1]. GSM owns a market share of more than 70% of the world's digital cellular subscribers. It is almost unimaginable to walk without a mobile phone.

[2] Designed an automatic door system using a unique wireless ID using Bluetooth technology. The system is to close and open the door of a car with a unique ID. The system is divided into three sections: sensing unit, controlling unit and a driving unit. The system

consists of a microcontroller- Arduino Leonard, transceiver, DC motor and a Bluetooth module. The developed system can only be assessed within a 30ft radius because signal transmission is by Bluetooth technology.[3] Designed and implemented a door locking system using the android app. The work presents a smart home controller that uses the Bluetooth feature of an android device to control the operation of the automated security door system. The Bluetooth module installed on the door receives the commands from the android phone and passes the command to the microcontroller that controls the opening and closing of the door. The door control is only possible within short proximity to it because Bluetooth coverage distance is only about 30 ft.

[4] Designed and implemented a versatile and intelligent home security system. The system was implemented based on the microcontroller to alert when an unauthorized person tries to enter the home, though SMS and Buzzer.

To make the system robust additional layers of security was incorporated by including security devices such as android based door password, manual keyboard to open the door, PIR motion to detect an unauthorized person in the home, rotating ultrasonic sensor by a servo motor to activate the camera to capture images and an RF transceiver to produce an audio signal to alert people outside the home. An Android phone and the microcontroller were connected through Bluetooth and all sensors outputs were being monitored by it. The ultrasonic sensor is used to detect an unauthorized person moving around the door. If someone tries to unlock the system, then the sensor will be activated. A pulse is received by the controller and the controller section activates the devices such as the GSM module, LCD, camera, RF Transceiver, and buzzer. During an electrical breakout, the system becomes vulnerable and door control will be possible until power is restored.

[5] Designed and implemented an automatic door opening and closing system using PIR. The system is designed to open the door as the user approaches the door and closes the door as the user departs. The door opening process is prompted by the PIR sensor which sends a trigger to the programmable microcontroller 8051. The microcontroller then sends a corresponding signal to the servomotor to act accordingly. The door is designed to give free access to everyone. It is evident from the reviewed literature that a lot of research has been done on mobile phone door control lock systems. Some of the implemented systems are of limited communication range. With most not having feedback opportunity and others with minimal security feature. Hence a need for a system with a wider assess coverage area, selective assess and opportunity to of door status update.

MATERIALS AND METHODS

In this section, the details of the design, hard and soft wares materials

used in the implementation are summarized.

Circuit Design

Figure 1 shows the block diagram of the mobile phone-controlled door lock system. It consists of a power supply unit that supplies the required power to other subsystems. The control unit consists of a programmable microcontroller - Arduino UNO and a GSM module – SIM800. The GSM module serves as the communication bridge between the user and the microcontroller. SMS messages from the user can be used to lock, unlock and inquire about the door status. The system is divided into two sections: Hardware and software.

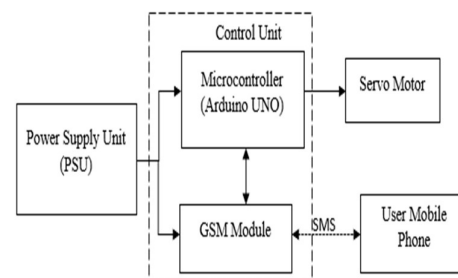


Fig 1: Block Diagram of the Mobile Phone-Controlled Door Lock System

Hardware Design and Selection

The hardware components used are Arduino UNO, servomotor, GSM module SIM800, 240V/12V 3A transformer, four diodes 1N4001, filtering capacitor 2000uf and 5V 2A regulator LM78S05.

A detailed analysis of the various hardware units is given below.

Power Supply Unit

This unit is made up of several sections, the system's components power requirement is considered in this design. The control unit requires a 5V 500mA for the Arduino UNO, while SIM800 requires between 3.4V - 4.4V and 1A current for reliable operation. The servo motor also requires 5V and a current of about

200mA. The power supply should be able to provide the combined current of 2A. Figure 2 shows the block diagram of the power supply unit.

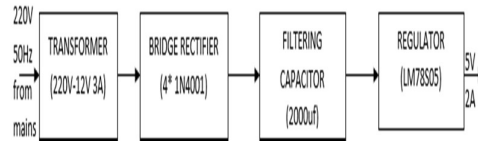


Figure 2: Block Diagram of the Power Supply Unit

The power supply unit consists of a step-down transformer that has an output of 14V AC with an output current of about 1A, a full bridge rectifier, a voltage regulator (7805) and a filter. The power requirement of the security system is 5V.

The transformer design and selection

The 220V AC from the mains is stepped down to 14V AC with the help of the transformer. The peak voltage output of the transformer is calculated using equation (1).

$$V_{peak} = \sqrt{2} \times V_{rms} \quad (1)$$

Where

$$V_{rms} = 14V$$

$$V_{peak} = \sqrt{2} \times 14$$

$$V_{peak} = 19.80V$$

Rectifier diode design and selection

Four 1N4001 diodes connected to the bridge were used for the full-wave rectification of the output voltage from the transformer. 1N4001 was chosen because its PIV (Peak Inverse Voltage) is 50V which is greater than V_{peak} which is approximately 20V. The value of the rectified voltage is calculated as follows.

$$V_{dc} = (2 / \pi) \times V_{peak} \quad (2)$$

$$\text{But } V_{peak} = 19.80V$$

$$V_{dc} = (2/\pi) \times 19.80$$

$$V_{dc} = 12.61V$$

Voltage Regulation Filter Design

For the section of the home security system which requires a 5V power supply, a 5V regulator (LM7805) was used. The choice is based on the IC's ability to keep its output voltage stable at 5V and it can provide up to 1A load current. LM7805 also have attached a heat sink to conduct the generated heat away from it under working condition. For the filter section, it is preferable to choose a filtering capacitor that holds the peak-to-peak ripples (RF) at approximately 70% - 80% of the peak voltage. The smaller the ripple factor the better the performance of the filter. Therefore, using design specifications, the value of the capacitor can be calculated as follows:

From the relations:

$$Q = C \times V \quad (3)$$

$$Q = I \times T \quad (4)$$

$$f = \frac{1}{T} \quad (5)$$

$$I_{min} = I_{dc} = 1A$$

Here, C is the filtering capacitor, Q is charge in colombs, I is current taken by the load, T is period in seconds and f is frequency in Hz. Using, equations (3) and (4) and substituting for T from equation (5), yields:

$$C = \frac{I}{Vf} \quad (6)$$

But V is the peak-to-peak voltage, and RF is the ripple factor. To calculate its value, the relation of equation (7) is used

$$V = RF \times V_{rms} \quad (7)$$

V_{rms} is given by $\sqrt{2} \times V_m$ where V_m is the system required voltage 5V, the mains frequency is 50Hz and the RF is 70%.

Therefore

$$V = 0.7 \times \sqrt{2} \times 5$$

$$V = 4.949 \text{ Volts}$$

$$\text{And } C = \frac{1}{4.949 \times 50}$$

$C = 4040\mu\text{f}$

The standard available value used is $4400\mu\text{f}$, where two $2200\mu\text{f}$ are connected in parallel. Figure 3 shows the circuit diagram of the power supply unit of the home security system.

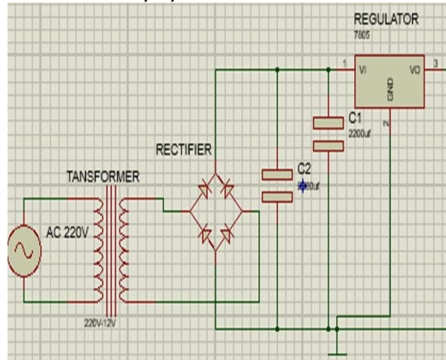


Figure 3: Circuit Diagram of Power Supply Unit

Control Unit: This unit comprises of Arduino UNO and the GSM module. **Arduino UNO** is a board embedded with ATmega328 a microcontroller, ATmega328 is an integrated circuit (IC) containing all the main parts of a typical computer, which are: Processor, Memories, Peripherals, Inputs and outputs [6]. It will provide required computing resource to achieve the aim. All communication and controls in this system pass through the microcontroller. The Arduino UNO has 14 digital input/output pins (of which 6 can be used as PWM-Pulse Width Modulation-outputs), 6 analogue inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an In-Circuit Serial Programming (ICSP) header, and a reset button. It contains everything needed to support the microcontroller. Arduino UNO board is shown in Figure 4.

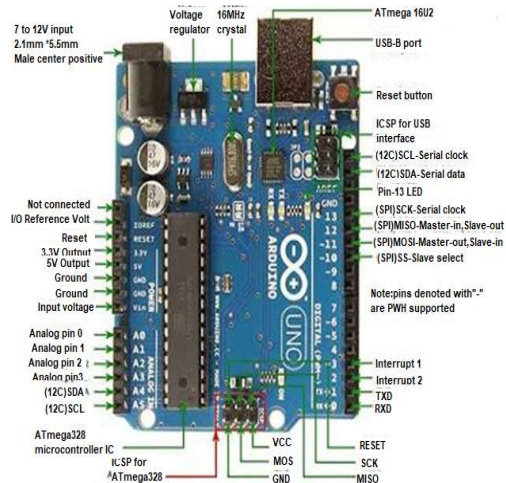


Figure 4: The Arduino UNO Board

GSM Module SIM800: SIM800 is a cellular communication module that can make calls, send email, SMS, and even connect to the internet. The module operates like a mobile phone, but it needs external peripherals to function properly. Figure 5 show the image of a SIM800 board.

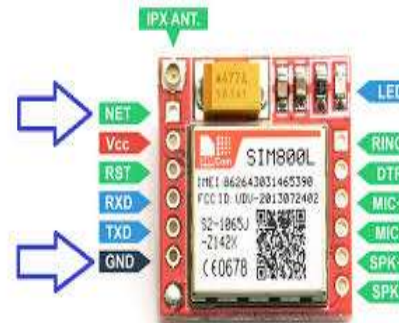


Figure 5: SIM800 Board

The module has audio channels which include a microphone input and a receiver output, a SIM card interface, and it is Quad band hence can connect to any global GSM network with any 2G SIM. The receiver pin (RXD) of the module is connected to transmitter pin (02) of Arduino while the transmitter pin (TXD) of the module is connected to the receiver pin (01) of Arduino, V_{cc} pin of the module is connected to the LM78S05 in voltage divider circuit and GND pin to the ground.

Communication speed (baud rate) depends on the board to be paired with, baud rate of 115200 was chosen, this rate allows for successful communication between SIM800 and Arduino UNO.

Output Section

The output section comprises of only the servo motor, which is the link between the controlled door and the system's control section.

Selection of Servo Motor: The servomotor motor used is SG90. The choice of SG90 is because it is tiny, light weight and high-power output, in extension a potable control system. Its current rating is about 270mA and can rotate 90 degrees in both direction, controls can be done with simple servo codes. SG90 has three pins, the ground pin is connected to common ground, V_{cc} pin connected to 5V from the power supply and PWM (signal pin) is connected to analogue pin A0 of the Arduino board.



Figure 6: Servo motor

The hardware of the system unit comprises of LEDs-which serves as indicators, resistors, GSM module (SIM800) and Arduino UNO. The receiver pin pin 0 of Arduino is connected to the transmitter pin pin Tx of SIM800 and the receiver pin pin Rx of SIM800 is connected to transmitter pin pin1 of the Arduino, the signal pin GPIO of SIM800 is connected to pin 9 of Arduino as showed in Figure 6. Power requirement of SIM800 is 3.3V 20mA. LED1 is connected to digital pin10, LED2 is connected to digital pin13, and Servo is connected to analogue pinA5 of the Arduino. The LEDs were connected in a series connection with resistors in a simple way to stabilize the current flowing through them.

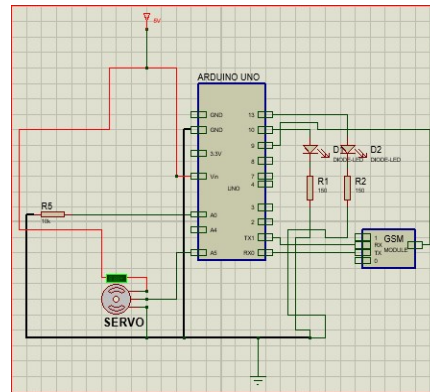


Figure 6: Circuit Diagram of GSM and Servo connected to Arduino UNO

LEDs voltage drop V_f is between 1.8V - 2.5V (a worst case is used in the design, 2.5V) and operating current I is 20mA, while V_s (supply voltage) is equal to 5V (from Arduino pin). Using these values, the value of the current limiting resistors can be obtained.

Ohms law, equation (8) was used to calculate the value of the Resistors R_1 and R_2), as shown.

$$R = \frac{(V_s - V_f)}{I} \quad (8)$$

$$R = \frac{(5 - 2.5)}{(20 \times 10^{-3})}$$

$$R = 125 \Omega$$

From the obtained value of 125 ohms a standard value of $150 \Omega \pm 20\%$ was chosen for R_1 and R_2 . The complete circuit diagram of the whole system with the power supply is shown in figure 7.

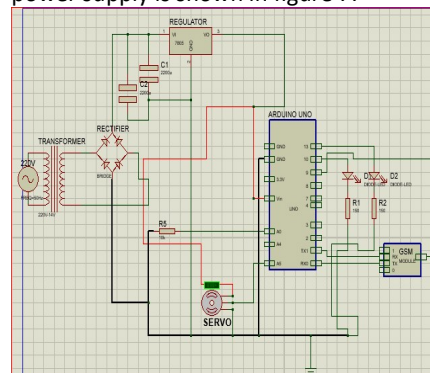


Figure 7: Circuit Diagram of the Complete System

Writing Source code for the microcontroller Arduino UNO

The source code is written to satisfy the requirement of system whose main controller is an Arduino UNO. The program was written in the Arduino IDE. The flowchart of Figure 8 was used as a guide in writing the program. The software for the process is presented in Appendix A.

SOFTWARE DESIGN METHODOLOGY

The software used in this work to control and synchronize the activities of all system parts to function as a unit is implemented using the flowchart in Figure 8. The software codes were written in Arduino integrated development environment (IDE) with Arduino programming language.

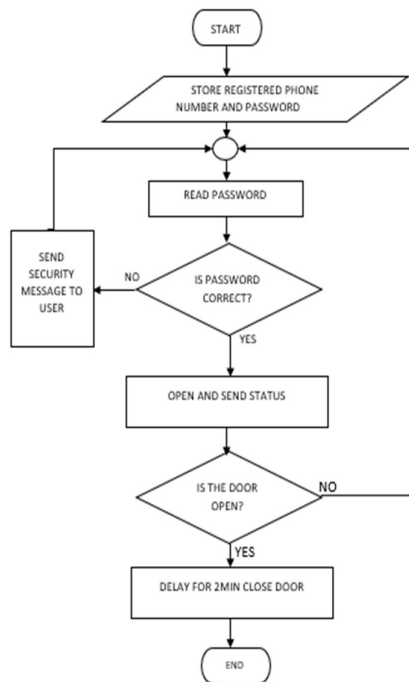


Figure 8: Flowchart of the control software

RESULTS AND DISCUSSION

Testing of the designed circuit and components

All the components used were tested to ensure workability before and

after physical construction of the system's prototype to ensure that all contacts and connections were made properly. Test was conducted at unit levels. The tests conducted were categories into hardware and software test.

This unit was initially designed and simulated using circuit wizard and proteus, this is to ascertain the circuit is working properly based on design specifications. After which the components are put onto breadboard for further testing and finally soldered on the vero-board. Figure 9 shows simulation of the power supply unit.

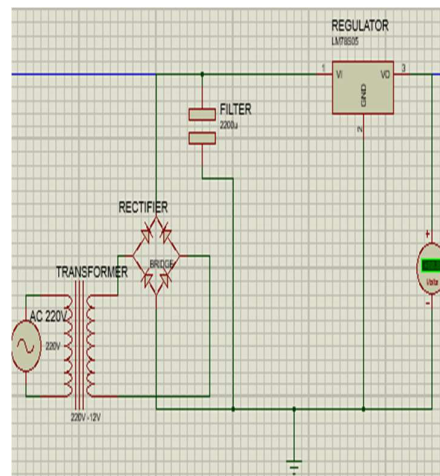


Figure 9: Screen Shot of the Power Supply during Simulation

Controller Unit

The controller unit comprises of the microcontroller board and the GSM module. Software was uploaded on the microcontroller and the response to stimuli from the GSM module was monitor via the communication 3 port (COM3) of the computer. This test makes it possible to understand what is happening inside the microcontroller. The GSM module has in it a registered subscriber identification module (SIM) card. Once the GSM module is connected to power, a blinking green led (with about 2 seconds interval) on it indicates a

successful connection to network. Software was also written in the microcontroller to output status of network connection. The software is presented in appendix A. Figure 10 presents the COM3 output during the test period.

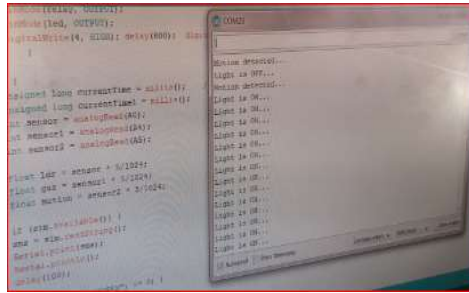


Figure 10: Software Test Result

Servomotor

The servo motor was set to initial 0 degree by writing to it through the microcontroller, to ensure proper alignment. The servomotor was also tested with DC battery to ensure it is functional

System Test

The full system test was to control the door lock open/close functions using a mobile phone and to be able to give door status information when required by the homeowner. The system was initially designed and simulated in proteus environment, to ensure the system is working perfectly based on design specifications. The system was constructed on a breadboard, this was to ensure proper arrangement in other to ensure a portable system. Finally, the system was implemented and tested on a Vero board.

Simulation Test

This simulation was carried out using Circuit Wizard, this helped in design of the circuit and testing it with software uploaded, to ascertain the circuit is working properly based on design

specifications. After which the components are put onto breadboard for further testing and finally soldered on the vero-board.

No - Load Test

This test was carried out when the circuit has been developed on a Vero board. A state at which the system is not faced with any control responsibility, this is the verification stage. Physical inspection was done to ensure all components and connections were in place. This was done by checking all closed tracks, jumper wires etc. for open or short circuit. Power was fed to the circuit for a minute. Fingertip was then used to sense the temperature of the components if any was overheating. Also, code inspection was carried out to ensure optimal use of memory, by employing DRY (Don't Repeat Yourself) technique. DRY technique is a principle in software development implemented to reduce software duplication. Being satisfied with this test result, load test then followed.

Load Test

At this stage, power consumption was monitored to ensure power specifications are met, with the voltmeter, the current consumption of the circuit was taken note of - when a response is required and when not. The response time to control was also monitored. For the software aspect, the performance of the code was scrutinized, the software was compiled and executed, parameters such as memory usage, CPU usage, response time and overall performance for the software were analyzed. Voltage test then followed. This was performed with a digital multimeter. Voltage and current level at different points on the board was taken and compared with design specification. Figure 11 shows the test diagram used during voltage and current consumption test.

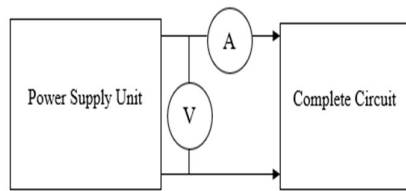


Figure 11: Test Diagram for Voltage and Current Consumption

The current consumption test of the system was carried out using two instances, when response is required and when not. This test was repeated several times and an average value computed. The voltage at the Arduino power pin was also monitored, to ensure conformance with design specifications. Results of the voltage and current test carried out are presented in Table 1.

Table 4.1: Voltage and Current Consumption Readings.

S/N	No load current (A)	Load current (A)	Voltage (V)
1	0.23	0.42	5.12
2	0.24	0.45	4.97
3	0.24	0.46	4.99
4	0.20	0.41	5.09
5	0.23	0.43	5.05
Average	0.228	0.434	5.044

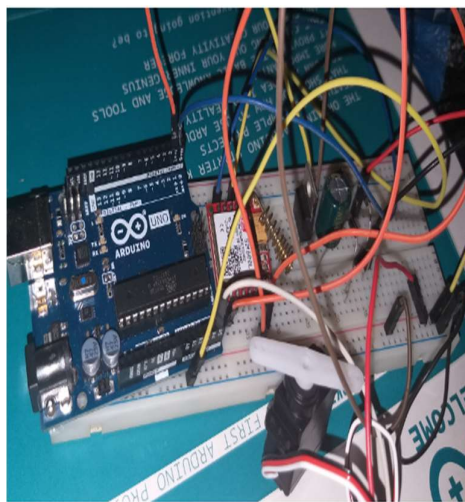


Figure 12: System on the Breadboard



Figure 13: The System Prototype

Reliability Test

The reliability test of the developed system was done using Part Count Failure Rate Techniques where reliability of a system is approximate as a relation of the units of parts used in the system design. Computation was done using relation with time to failure test. During this test, values of data are recorded which can be put into cumulative function, $F(t)$. Reliability is express explicitly by equation 9 [10]:

$$F(t) = 1 - R(t) \quad (9)$$

The method used in calculating the reliability of system requires information like part category, part quantities and quality factor. The system failure rate is defined in equation (10) [11]. Where F_i is given as failure rate of ith part, n is number of part category, N_i is quantity of the part and π_{Q_i} is the quality factor of the ith part:

$$F = \sum_{i=1}^n N_i F_i \pi_{Q_i} \quad (10)$$

The failure rate of each unit was computed using equation (9) with data from reliability prediction of electronic equipment handbook table [11]. The calculated failure rate of the security

system is presented in Table (4.2). Equation (10) was used to compute the value of the reliability of the system.

Table 4.2: Calculated Failure Rate of the Home Security System

S/N	Components	$F_i / 10^6$ hours	N (category)	N_i (units)	π_{Q_i}	$F10^{-5} / 10^6$ hours
1	Resistors	0.000196	1	3	0.03	1.764
2	Capacitors	0.000002	1	2	0.01	0.004
3	ICs	0.73	1	1	0.0043	313.9
4	Microcontrollers	0.015	1	1	2.4	3600
5	Semiconductors	0.0038	2	6	8.0	364.8
6	Mechanical device	0.083	1	1	0.103	854.9
7	Modules	0.028	1	1	0.26	728
8	Inductive devices	0.0030	1	1	0.30	90
9	Connector	0.040	1	2	0.659	5272
10	Contact/Hand soldering	0.0064	1	23	0.0013	19.136
11	Total failure rate of the system					11244.504

From Table 4.2 the predicted failure rate of the home security system was computed to be $11244.504 \times 10^{-5}/10^6$ hours. Using equations 9, reliability of the home security system was computed.

$$R(t) = 1 - 0.11244504$$

$$R(t) = 0.88755496$$

$$R(t) \approx 0.89$$

CONCLUSION

This work detailed the design and implementation of a mobile phone control door. The hardware and software designs were carried out. The system is light weight, potable and with a calculated reliability of about 89%. The assembled and programmed system was tested and found operating perfectly. The system can help to reduce the spread of infectious diseases, which can be transferred through door handles, it can also be used for especially people with disability and the elderly to ease the stress of opening and closing of their door.

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