

Secured Home Automation System with Improved Bluetooth Range for Remote Area Dwellers

¹Yahaya Salisu, ²Ikechiamaka Florence, ³Akinsanmi Akinbolati, ⁴Abdullahi Sanusi Ahmed
email: ahmadjidda2012@gmail.com, (08033364852), fosuagw@fudutsinma.edu.ng (+2348065631514), aakinbolati@fudutsinma.edu.ng
(+2348033955156), sanusuaabdullahi@gmail.com (+2348133061328)

¹Department of General Studies Education, Yusuf Bala Usman College of Education and Legal Studies, Daura, Katsina State. ^{2,3,4}Department of Physics, Federal University Dutsinma,,Katsina State, Nigeria

Abstract

The widespread diffusion of contemporary technology facilitates streamlined and facile communication between individuals and electronic apparatus. The utilization of current technological advancements in product or system design holds considerable potential for enhancing the quality of human existence, thereby making substantial contributions to societal progress. Notably, devices such as remote controls and GSM cell phones offer efficient means for the monitoring and control of domestic appliances, obviating the drawbacks associated with conventional mechanical switches, including the presence of numerous wires, susceptibility to electrical hazards, and heightened energy consumption. This scholarly article delineates the conceptualization and realization of a sophisticated, adaptable, and secure home automation system utilizing components such as the Bluetooth module HC 05, Arduino Uno featuring ATmega 328, buck converter, relays, and the Android operating system. The implemented Home Automation System empowers the operation of household lighting switches, fans, televisions, and other appliances with a 10A capacity through a smartphone application leveraging Bluetooth wireless technology. Two distinct command mechanisms govern the system: voice commands and button presses facilitated by an Android application. A voice recognition system has been integrated as a security measure to safeguard against unauthorized access. The system's operational range extends up to 125m without obstructions in both outdoor and indoor environments, but a reduced range of less than 50m is observed in scenarios involving obstacles both indoors and outdoors. Signal strength exhibits a diminishing trend with increasing distance. Significantly, the system's applicability extends to remote areas devoid of internet connectivity.

Index Terms: Home automation, Bluetooth, Remote dwellers, Arduino, Buck converter

1. Introduction

The expanding global demographic necessitates a simultaneous advancement and simplification of technological communication methods. A pivotal requirement emerges for effective communication modalities between individuals or devices, encompassing both wired and wireless means. Many nations are adopting communication-centric control and monitoring frameworks within smart grids to address the proliferation of extensive wiring and significantly reduce power consumption. Within this context, home automation stands out as a highly promising facet of the Internet of Things (IoT), contributing to improved quality of life, especially for individuals with disabilities or those seeking enhanced comfort.

The mitigation of the risk of electrical shocks becomes a crucial outcome, significantly enhancing the security of buildings. The integration of Bluetooth and Arduino smart systems emerges as an efficacious means to achieve these objectives. This scholarly investigation specifically focuses on

conceptualizing and realizing an automated electrical appliance switching system. This system utilizes the Arduino Uno, a buck converter, and a Bluetooth module, offering control through the Android operating system on a mobile device. The widespread adoption of smartphone systems, evident in numerous research endeavors utilizing Bluetooth modules, underscores the commendable results yielded by such technologies. This study builds upon prior research contributions, notably '[2],' in its endeavor to devise a Home Automation System (HAS) employing an Arduino Mega2560 microcontroller with Internet Protocol (IP) connectivity for remote access and control of diverse devices and appliances. The implemented functionalities encompass the manipulation of light switches, power plugs, and temperature sensors through either a web browser interface or a Bluetooth module. Additionally, a voice recognition system has been implemented utilizing an Arduino Uno, Android operating system, and a Bluetooth module, contributing to the system's versatility. In contrast to prior configurations, the present study introduces a dual-control mechanism, integrating both voice commands and manual commands initiated by pressing buttons on an Android smartphone. The Bluetooth-enabled home automation system utilizing Arduino takes center stage in our investigation, providing a comprehensive approach to address diverse user preferences and needs. Another significant contribution, '[4],' utilized an Arduino Uno, a smartphone, a step-down transformer, a Bluetooth module, and relays to develop a Home Automation System (HAS). This system demonstrated proficiency in controlling the air conditioning unit (AC) and electrical switches for lighting and fans through an Android phone interface within the designated environment, eliminating the need for voice commands. Furthermore, '[6]' highlighted the adaptability of Bluetooth technology for ease of communication. An Arduino Uno and relays were utilized in their system, showcasing the control and monitoring capabilities of home appliances using an Android phone. However, this system did not incorporate a voice recognition unit. '[7],' on the other hand, utilized Arduino to create a HAS interface, regulating the operation of electrical appliances through an Android phone and a Bluetooth module. Notably, this system lacked a voice recognition unit. In a separate endeavor, '[8],' introduced a web-based technology for controlling home appliances, demonstrating that smart homes can reduce consumption without posing technological risks. However, this system requires internet access and lacks a voice recognition feature, unlike the design presented in this study, which caters to locations with or without a network. Moreover, '[9],' designed and implemented a system capable of controlling electrical switches, water levels, and temperature using Bluetooth and Android in conjunction with servo motors and relays. While the water level and temperature were displayed on a liquid crystal display (LCD), this system lacked both security and a voice recognition system. Lastly, '[10],' presented a HAS design based on an Arduino UNO board, with home appliances connected to the board's input/output ports via relays. Wireless communication between the smartphone and the Arduino UNO is facilitated by a pairing password for each user, ensuring security. However, this system does not have internet access and is noted for its complexity, making it less cost-effective.

2. Materials and method

This paper details the components of the system, including Arduino Uno ATmega 328, Bluetooth module HC-05, Relay drivers 5V 10A, Buck converter 12VIN 5VOUT, TIP 41 Transistor, Battery, 12V DC Bulbs, and lamp holders, all arranged on a vero board. The system design methodology

involves creating a block diagram for visualizing the system structure and guiding the design process. Functional testing is carried out systematically, starting with the power supply and Buck converter, ensuring correct pin configurations. Each unit is assembled on the vero board, and thorough testing using a multimeter is conducted at each stage to validate functionality and output. This rigorous testing process guarantees the reliability and precision of the device throughout its development.

3. Design of Different Stages of the system

Figure 1 illustrates the block diagram guiding the construction of the entire system. The diagram outlines the hardware interconnections forming the system. The power supply links to a buck converter, reducing the voltage to the required 5V for the Arduino Uno, and subsequently to a 5V 10A relay, both connected to the Arduino. The relay functions as a switch, receiving microcontroller commands to control fans and televisions.

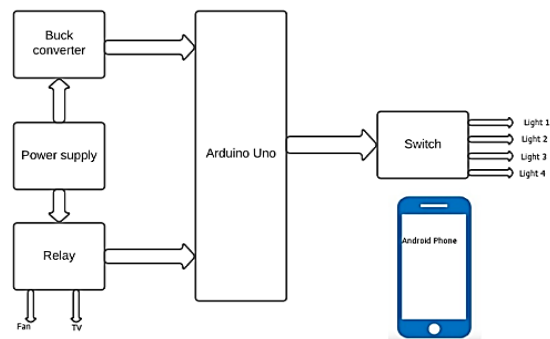


Fig: 1 Block Diagram of the HAS

A swiftly responsive transistor is incorporated into the system, controllable by a microcontroller and linked to Arduino pins facilitating pulse width modulation (PWM). The HC-05 Bluetooth module is additionally interfaced with the Arduino. The ultimate setup involves an Android phone equipped with a downloaded Arduino Bluetooth application, enabling seamless wireless communication and execution of pre-programmed commands between the interconnected devices.

3.1 Design of the Buck Converter

The buck converter for the system was designed based on the following components as in figure 2. The IC used was selected based on its Data sheet specifications.

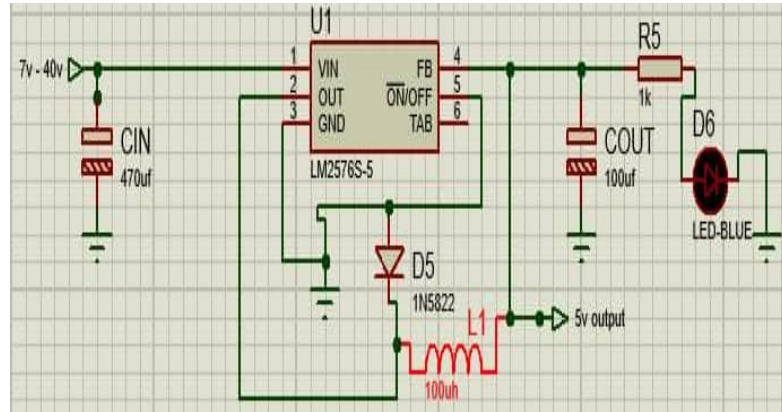


Fig:2. Buck converter circuit

On a Zero board, all components were meticulously connected and soldered using soldering wire, ensuring precise polarity. Rigorous precautions were taken to guarantee the proper functioning of the converter. The design aimed to step down the 12V DC source to 5V, serving as the power supply for the Arduino while safeguarding it from potential damage. Referring to the LM2576 datasheet [11], a converter designed in such a manner is expected to achieve 90% efficiency, utilizing an inductor within the range of 47µH to 330µH and a Schottky diode, specifically 1N5822. The Buck converter implementation followed the subsequent steps:

Basics of the design

Nominal voltage output $V_{out} = 5V$

Nominal voltage input $V_{in} = 12V$

Estimated efficiency 97%

$$E = \frac{P_{out}}{P_{in}} \times 100 \tag{1}$$

Some of the values in the design were obtained from the data sheet of the IC used in the design

Duty cycle is given using the equation below

$$D = \frac{V_{out}}{V_{in}} \quad D = \frac{5}{12} = 0.417 \tag{2}$$

The duty cycle's magnitude is contingent on the output voltage, with an elevation in output voltage correlating to an increased duty cycle. Conversely, an upsurge in input voltage results in a reduction in the duty cycle, indicating the operational status of the buck converter. The observed duty cycle value confirms that the output voltage falls below half of the input voltage, as it does not reach 50%. This outcome aligns with the intended design specifications. Input power $P_{in} =$

$$I_o V_o \tag{3}$$

$$P = 6 \times 12 = 72W$$

Since the estimated efficiency is 97% therefore the power output can be obtained by

$$P_o = E \times P_{in} \tag{4}$$

$$P = 0.97 \times 72 = 69.48W$$

Therefore, the output current will be obtained from

$$P_{in} = I_o V_o$$

$$I_o = \frac{P}{V} \quad (5)$$

$$I = \frac{69.48}{5} = 13.75$$

The output current measurement reveals that the converter amplifies the current from 6A to 13.97A. This occurs as, during the switch's ON state, the load resistance (RL) draws current from the battery, and during the OFF state, it receives current from the inductor. Combining these two currents results in a cumulative value greater than the current discharged by the battery over a given period. The voltage across the inductor can be determined from:

$$V_L = V_{IN} - V_{OUT} \quad (6)$$

$$V_L = 12 - 5 = 7V$$

The inductors and capacitors value were selected based on the specification obtained from the Data sheet of the IC used in designing the converter viz LM2576''[11]. The constructed buck converter is shown in figure 3.

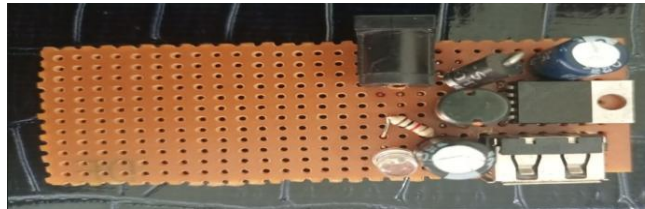


Fig: 3 Designed Buck converter

3.2. Design of the switch of the system

The system switch is designed to respond intermittently to commands, aligning with the contemporary trend in electrical switches. Power transistors, such as the TIP41, were chosen for this purpose due to their capacity to accept commands from a microcontroller and their swift switching speed. The resistance value for the system switch was determined directly from the TIP41 transistor's datasheet.

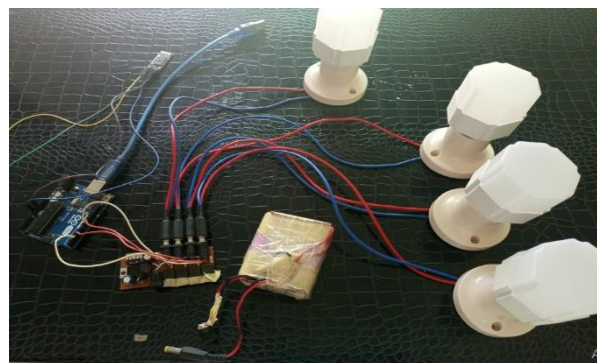


Fig: 4 Switching system with bulbs

Four TIP41 transistors were selected to control four appliances. In Figure 4, these transistors function as switches, with their collectors and emitters connected to the 12V bulb female port adapters. The transistor bases are directly linked to the Arduino's microcontroller via PWM-supporting pins: switch one to pin 10, switch two to pin 9, switch three to pin 4, and switch four to pin 5. Utilizing the microcontroller's capacity, it activates the transistors, executing commands promptly without providing feedback due to the power transistor's swift operation. Special connecting wires from Arduino were avoided due to their looseness during testing; instead, soldering wire was used to ensure secure connections at the base of each pin for optimal system functionality. Figure 5 displays the switch system connected to relays. The second part of the switching system connected an electrical relay 12V 30A to the Arduino to serve as the switching circuit for controlling fans and TVs in the house.

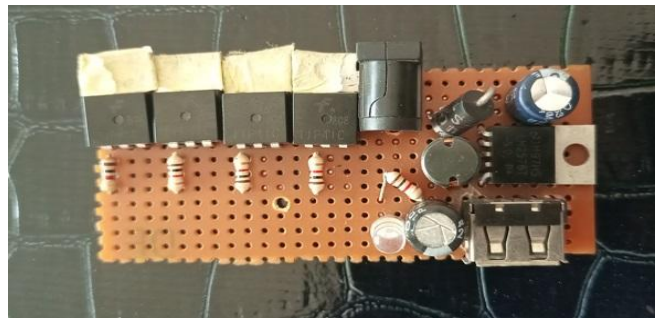


Fig: 5 The Switch System Connected to Relays

The second part of the switching system connected an electrical relay 12V 30A to the Arduino to serve as the switching circuit for controlling fans and TVs in the house.

The relay is powered by 250 volts. The circuit was wired with a BC527 transistor and a 1kohm resistor. The relay's output is connected to Arduino pins 2 and 6. Figure .6 depicts the system's circuit diagram.

In the above circuit the comparators serve as the pins of the Arduino.

3.3. Connection of Bluetooth Module to the Arduino

The Bluetooth module has four pins which were connected as follows

GND to GND of the Arduino

Vcc to Vcc of the Arduino

TX to RX of the Arduino

The Bluetooth module will function effectively if the aforementioned connection is made. Failing to do so could result in module damage. The system is powered by a battery that is located close to the Arduino and has a six-hour battery life. The complete circuit of the designed HAS is shown in figure 7

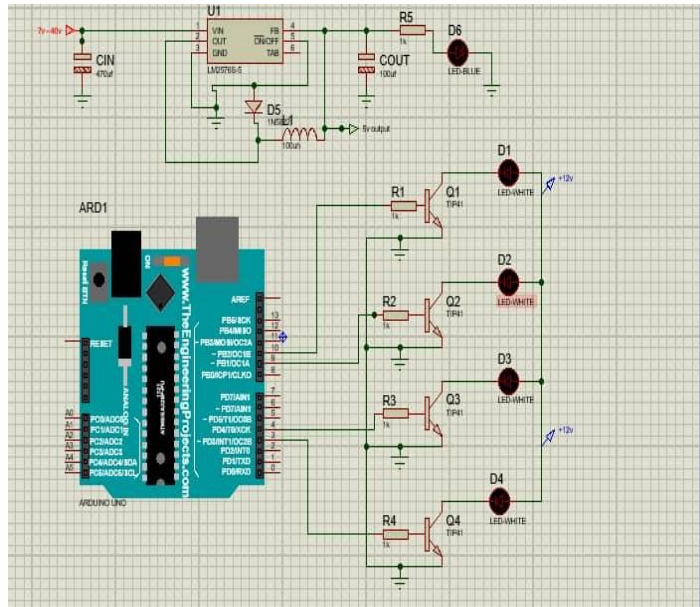


Fig: 6 Circuit diagram of Switching System Connecting the Arduino to the Relay

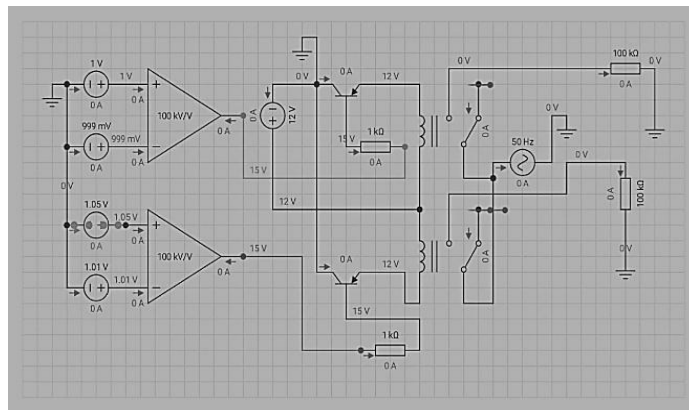


Fig: 7 Complete Circuit diagram of the Designed HAS

4. Implementation of the System

Various tests were conducted at diverse locations to validate the operational effectiveness of the system, yielding noteworthy outcomes across all testing environments. End-users possess the capability to employ a mobile phone for executing control functions by either activating specific buttons or utilizing voice commands, contingent on the specific task. The system's responsiveness to commands is predicated on the Arduino coding.

The system's testing phase encompassed four distinct scenarios:

- i. Indoor environment devoid of obstacles
- ii. Unimpeded outdoor space
- iii. Indoor setting with barriers

iv. Outdoor space with obstructions

The above-mentioned cases were tested successfully at Katsina Community College of Arabic and Islamic Studies in Katsina, Katsina State (Nigeria). The range of the signal strength was measured at various distances with and without obstacles using a measuring tape. The tests were carried out at various distances with and without obstacles in order to determine the translational distance, as well as distances around corners and obstacles.

5. Results and Discussion

The intended culmination of this study involves the realization of a home automation system. This project has successfully developed an automated system for the convenient control of household appliances such as lights, fans, and air conditioners. The performance evaluation of the buck converter, tested with a 12V DC supply and connected to a voltmeter, demonstrated seamless functionality in all scenarios. Additionally, a mobile phone was successfully charged through the system's buck converter. The testing results are summarized in Table 1.

Table 1. Result of Testing the System

Indoors				Outdoor			
With Obstacle		Without Obstacle		With Obstacle		Without Obstacle	
Range (m)	Observation	Range (m)	Observation	Range (m)	Observation	Range (m)	Observation
20	Connected	20	Connected	20	Connected	20	Connected
40	Connected	40	Connected	40	Connected	40	Connected
60	Disconnected	60	Connected	60	Disconnected	60	Connected
80	Disconnected	80	Connected	80	Disconnected	80	Connected
100	Disconnected	100	Connected	100	Disconnected	100	Connected
125	Disconnected	125	Connected	125	Disconnected	125	Connected

Based on the experimental results, the Bluetooth range has been verified to extend to 125 meters, albeit with a marginal increase. Signal propagation, however, is susceptible to environmental impediments, such as walls and metallic surfaces, resulting in signal degradation and interference. Bluetooth, operating on radio waves (RW), encounters absorption by materials, particularly metals, influencing signal integrity [12]. Noteworthy impacts on Bluetooth signal were identified in the presence of walls, metals, refrigerators, and the human body at certain distances [13]. The paper underscores the necessity of signal boosters for widespread deployment in venues like mansions, schools, industries, and hospitals. Bluetooth signal repeaters and extenders emerge as viable solutions, with repeaters functioning akin to amplifiers in areas with weak Bluetooth signals, and extenders not only amplifying but also extending signals to other regions. Signal repeaters are reported to enhance Bluetooth signals up to a range of 1000 feet (307.3 meters) [14]. In the implementation of these systems, specific network topologies are recommended, including Mesh and Star topologies. Star topology, characterized by a central hub connecting hosts, is suitable for applications in mansions and secondary schools. On the other hand, Mesh topology, wherein every host communicates directly with every other host, is proposed for extensive areas with machinery,

such as factories. Bluetooth's inherent capability to function as both slave and master, accommodating multiple slaves and masters, aligns with these network configurations. Regarding the security of the home automation system, stringent measures have been implemented. The system is programmed to recognize authorized voices and Android phones, requiring explicit authorization through voice commands. The deliberate avoidance of fixed voice recognition is motivated by safety concerns, emphasizing the significance of securing user phones to prevent unauthorized access to commands and the system.

6. Conclusion

Addressing the paramount concerns of security and privacy in home automation, this study introduces a meticulously crafted system based on Arduino and Bluetooth standards. Designed to operate in areas without internet access, the system combats potential security threats, especially concerning utility charge data. By enabling programmed communication among electrical appliances, the system significantly reduces energy consumption, minimizes hazards, eliminates extensive wiring, and enhances comfort, particularly for the elderly. This research signifies a transformative stride towards heightened efficiency, security, and convenience in home environments.

7. References

- [1]. S.Y Kim et al., "Design of a High Efficiency DC–DC Buck Converter With Two-Step Digital PWM and Low Power Self-Tracking Zero Current Detector for IoT Applications," in *IEEE Transactions on Power Electronics*, vol. 33, no. 2, pp. 1428-1439, Feb. 2018, doi: 10.1109/TPEL.2017.2688387.
- [2]., N. David., Chima, A., Ugochukwu, A., Obinna, E. and Research, E. (2015). Design of a home automation system using arduino. 6(6), 795-801.
- [3]. Sen, Sonali & Chakrabarty, Shamik & Toshniwal, Raghav & Bhaumik, Ankita. (2015). Design of an Intelligent Voice Controlled Home Automation System. *International Journal of Computer Applications*. 121. 39-42. 10.5120/21619-4904.).
- [4]. A Raheem,. (2017). Bluetooth based smart home automation system using arduino UNO microcontroller. (27).
- [5]. A. Krishnan V., Priyadarshini, J. I., and Sivaranjani, T. 2017 Smart Home Automation System Using Arduino, ISSN: 2277-9655 March, 2017 Impact Factor: 4.116 IC™ Value: 3.00 CODEN: IJESS7
- [6]. M Mahith., Kumar, D. S., Prajwal, K., and Dakshayini, M. (2018). Bluetooth Home Automation. Paper presented at the 2018 Second International Conference on Green Computing and Internet of Things (ICGCIoT).
- [7]. N. Chinwe Juliana Construction Of Home Automationcontrolsystemusing Bluetooth Volume 5, Issue 1, 2021 ISSN: 2617-3522 DOI: <https://doi.org/10.31058/j.am.2021.51002>
- [8]. O Ajibola., Balogun, A. J. J. o. A. S., and Management, E. (2019). Development of Smart Switch for Household Appliances Using Web-Based TechnologyDevelopment of Smart Switch for Household Appliances Using Web-Based Technology. 23(1), 145–149-145–149.

- [9]., M Mamun & Hossain, Mohammad & Rahman, Md. Atiqur & Abdullah, Md & Hossain, Md. (2020). Smart Home Automation System using Arduino and Android Application. 10.5281/zenodo.3816960
- [10]. P. Sharma, Agarwal V, Nayyar T, Awasthi T. Bluetooth Home Automation System. ijebm [Internet]. 29Oct.2021 [cited 4Nov.2022];5(5). Available from: http://www.journalrepository.theshillonga.com/index.php/ije_bm/article/view/4120.
- [11]. T Electronics Data sheet of LM2576
<https://www.alldatasheet.com/datasheet-pdf/pdf/530550/TGS/LM2576.html>
- [12]. M Maditsha. (2017). Android enabled home automation system (via Bluetooth). BUSE,
- [13]. D. Labrique. (2020). Effects of Obstructions on the Accuracy of Bluetooth Contact Tracing. dlabrique@gmail.com Independent Researcher, Towson, MD, USA
- [14].D.S Kushwaha, A Singh Bluetooth wireless Technology and its Application ISSN: 2319-7064 SJIF (2019): 7.583.