Modern Energy-Efficient Living: Development of A Sound-Responsive Smart Lighting System

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ABSTRACT

This research developed a Sound-Responsive Smart Lighting System, enhancing home automation and energy efficiency. Utilizing an Arduino Uno R3 microcontroller, an ACE6467 microphone sensor, and an ACE6363 5V relay module to operate a 220V bulb. The authors developed the control logic directly within the Arduino Integrated Development Environment (IDE), creating a program that processed acoustic signals and converted them into digital commands to toggle the light's state.

The primary objective was to enhance accessibility for individuals with limited mobility while reducing the reliance on physical contact for device operation. Systematic testing was conducted in a controlled indoor environment to evaluate the performance of various auditory triggers, including claps, finger snaps, and object tapping, across distances ranging from 0.5 to 2.0 meters. Experimental results indicated that the system achieved "Excellent" responsiveness when triggered by a single clap up to a maximum effective range of 2.0 meters. However, performance significantly declined with higher-frequency sounds like snapping or tapping at distances beyond 0.5 meters, revealing limitations in sensor sensitivity and environmental noise interference.

The study concludes that while the Arduino-based Sound-Responsive Smart Lighting System is a highly effective tool for modern home automation, future iterations require more advanced sound-processing algorithms to further optimize energy conservation and minimize false triggering. This research serves as a technical blueprint for cost-effective smart home technology and a foundation for future advancement in sensor-based systems.

Keywords: Smart Lighting System, Arduino Uno R3, Sound-Responsive Technology, Home Automation, ACE6467 Microphone Sensor, Accessibility, Energy Efficiency.

INTRODUCTION

This research focuses on building a Sound-Responsive Smart Lighting System using an Arduino Uno microcontroller. The system works by using a sound sensor to "listen" for noises (like a clap), a relay module to safely turn the light on or off and a 220 volts light bulb as a light source.

In the study of Luaha et al. (2023), Electrical energy is a fundamental necessity for modern society. However, a significant amount of electricity is wasted when lighting systems remain active while not in use. On average, lighting accounts for 20% to 50% of total energy consumption. To prevent unnecessary costs and resource waste, it is essential to implement energy-saving measures. This can be achieved by developing more efficient ways to control and manage the power supply of electronic equipment.

The Sound-Responsive Smart Lighting System functions by employing a sound-sensitive transducer to detect specific acoustic impulses. Upon detection, the circuit modulates the power supply to a load, such as an LED or a high-voltage appliance. These systems offer significant advantages in home automation and industrial efficiency, providing hands-free operation for a wide range of electronic devices. Beyond handclaps, the device

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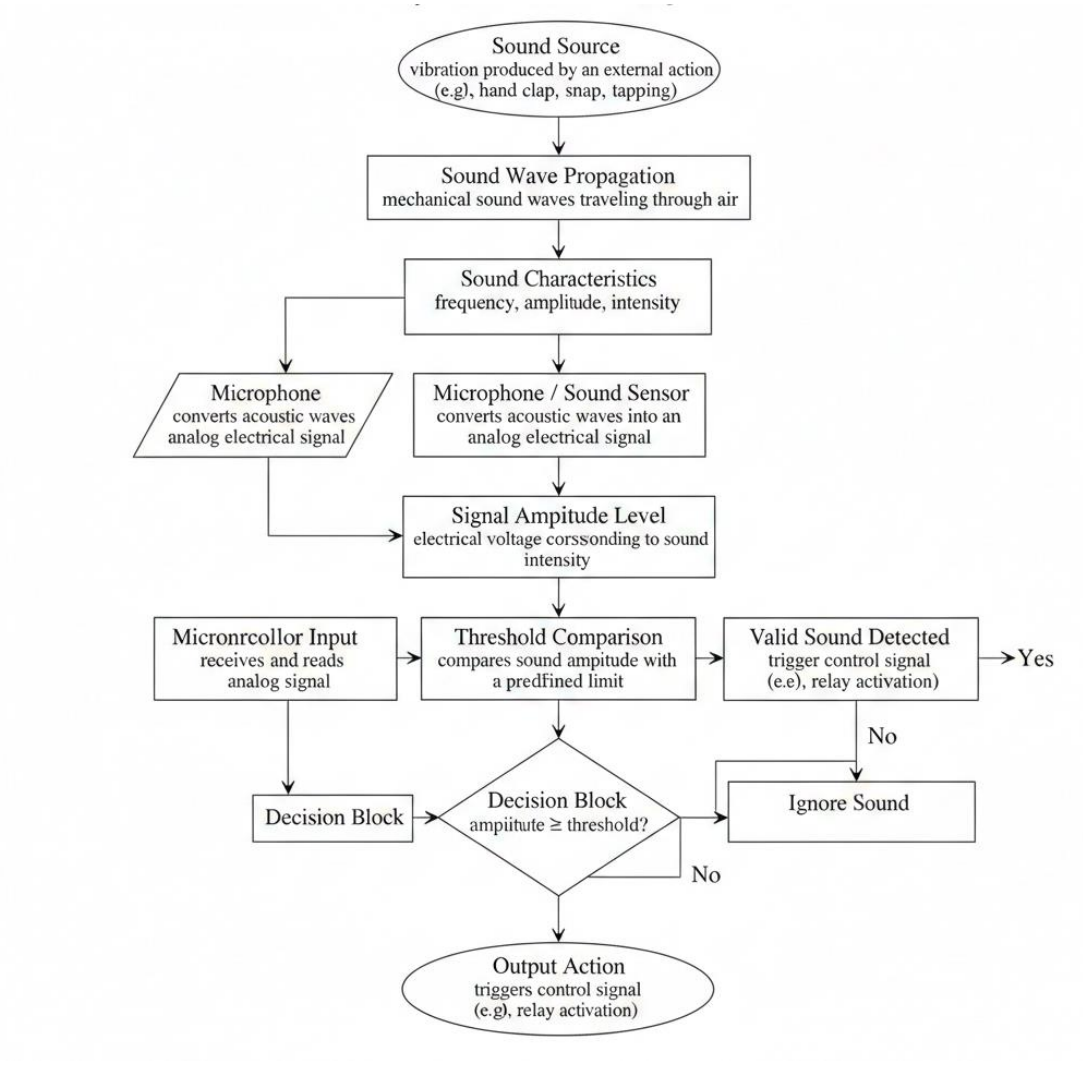
can be calibrated to respond to various auditory stimuli, including percussive sounds or speech (Tharani et al., 2024). In today's world, smart home technology is no longer just a luxury; it has become an important tool for saving energy and making life easier. A common problem in many buildings is that lights still rely on manual switches. This can be difficult to use for people with disabilities or inefficient in large spaces. By using a sound sensor and a microcontroller, a clap sound can be used to control a switch of a device. The clap switch does not need a physical contact from the person to control the switch (Jiwondano, 2016)

REVIEW OF RELEVANT THEORY, STUDIES, AND LITERATURE

This chapter presents the theoretical foundations, related studies, and relevant literature that support the development of the Sound-Responsive Smart Lighting System. It discusses key concepts in sound detection, microcontroller-based automation, smart lighting systems, and energy efficiency, as well as previous research closely related to the present study.

Relevant Theories

Figure 1. Sound Wave Theory And Acoustic Signal Detection



Sound is a mechanical wave produced by vibrations that travel through a medium such as air. These waves are characterized by frequency, amplitude, and intensity, which determine how sound is perceived and detected. In sound-responsive systems, microphones or sound sensors convert acoustic waves into electrical signals. The amplitude of the sound wave is directly related to the voltage output of the microphone sensor, which can be processed by a microcontroller. According to basic acoustic theory, louder sounds such as hand claps generate higher signal amplitudes, making them more suitable for triggering electronic systems compared to softer or higher-frequency sounds like snapping or tapping.

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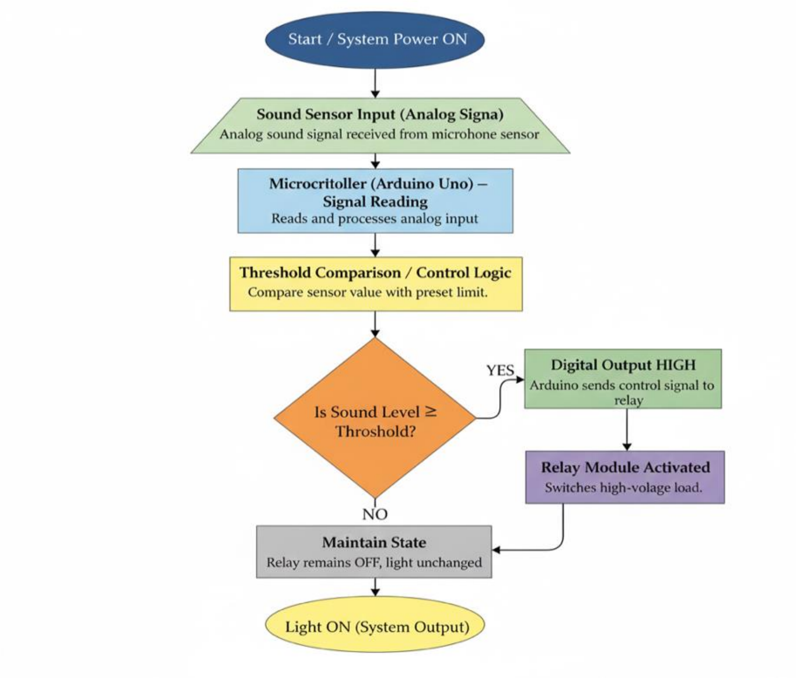
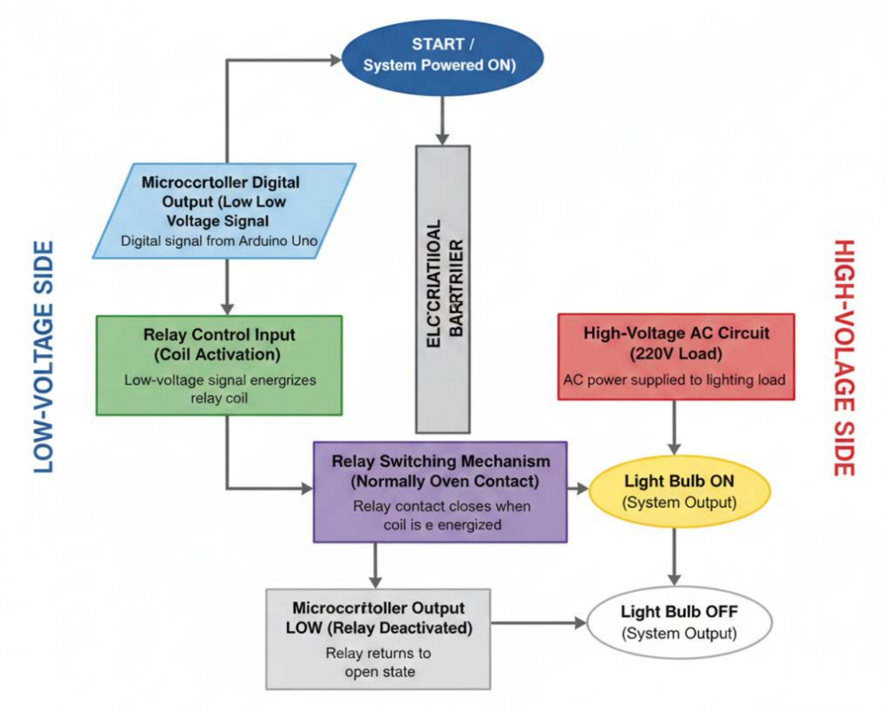
Figure 2. Microcontroller-Based Control Theory



Microcontrollers operate as embedded control systems that process input signals, execute programmed logic, and generate output signals. Control theory explains how systems respond to inputs based on predefined conditions or thresholds. In this study, a limit-based control logic is implemented, where the Arduino Uno compares the sensor's analog input with a preset threshold value. When the detected sound exceeds this limit, the controller issues a digital output to activate a relay. This ON–OFF (binary) control mechanism aligns with fundamental digital control theory, where systems operate between two discrete states.

Figure 3. Relay Switching And Electrical Isolation Theory



Relays function as electrically isolated switches that allow low-voltage control circuits to safely operate high-voltage loads. According to switching theory, relays prevent direct electrical contact between control and load circuits, reducing the risk of damage and ensuring user safety. In sound-activated lighting systems, the relay

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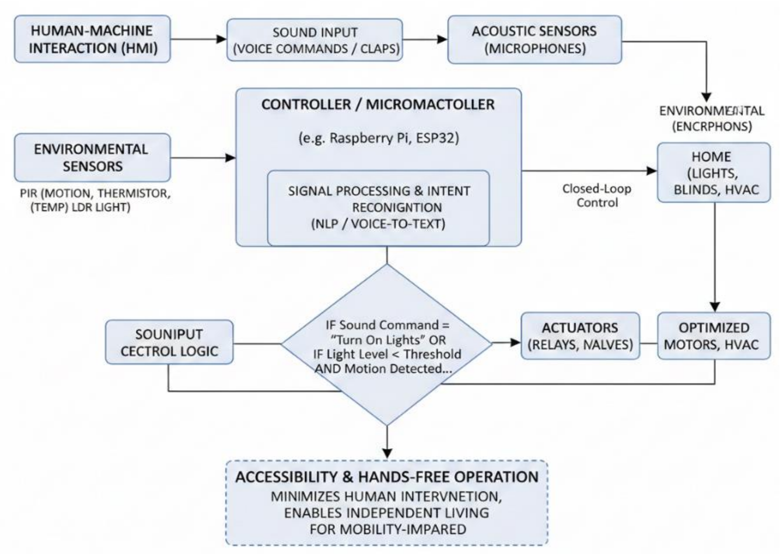
serves as an interface between the microcontroller and the 220V AC lighting load, enabling safe and reliable operation.

Figure 4. Smart Home And Automation Theory



Smart home systems are based on automation theory, which emphasizes minimizing human intervention while maximizing efficiency and convenience. Automation integrates sensors, controllers, and actuators to create responsive environments. Sound-responsive systems are a subset of human–machine interaction (HMI), enabling hands-free operation and improving accessibility, particularly for individuals with mobility limitations.

Review Of Related Studies

Several studies have explored sound-based automation and smart lighting systems using microcontrollers. Luaha et al. (2023) designed a clap detection light control system using Arduino Uno, demonstrating that sound-based switching can significantly reduce unnecessary energy consumption. Their findings support the present study's objective of improving energy efficiency through automated lighting control.

Darma et al. (2024) developed an automatic lighting system using a sound sensor and reported that clap-based activation provides reliable control within a limited range. Their study emphasized the importance of sensor sensitivity calibration, which aligns with the observed performance limitations in the current research when detecting snapping and tapping sounds at longer distances.

Fauziah (2022) investigated a sound-detection-based smart lighting system and highlighted challenges related to false triggering caused by environmental noise. The study recommended improved signal processing and filtering techniques, supporting the present study's recommendation for more advanced sound-processing algorithms.

Mamahit et al. (2023) explored voice-controlled lighting systems using Arduino Uno R3 and demonstrated that microcontroller-based automation enhances user convenience and accessibility. Although their system focused on voice commands rather than claps, their results reinf

Background of the Study

According to Adam et al. (2023), Technological evolution has fundamentally changed how humans interact with their environment, particularly regarding artificial lighting. The transition from glowing metal filaments to sensor-based activation—triggered by sound or movement—highlights a shift toward seamless, automated living. These advancements demonstrate how modern inventions serve to simplify daily tasks and enhance functional living spaces. Most electronic devices operate using electrical signals that switch between two states: ON and OFF. Because of this, switches play a crucial role in allowing electronic circuits to function, as they control whether a device is active or inactive. These switching components are widely used in engineering and are found in many machines and electronic systems that support modern technology. One example is a clap-activated light switch, which turns a light on or off when it detects a sound—such as a hand clap.

In a study conducted by Darma et al. (2024), A sound sensor is a device that can detect sound waves in its surroundings and convert them into signals that can be processed by a microcontroller. The use of microcontrollers in home automation is growing with the increasing need for convenience and efficiency. Microcontrollers enable accurate and responsive control of a variety of household devices, including lighting, security systems, and other electronic devices. By utilizing basic electronic circuits, microcontrollers can be integrated with various sensors, such as sound sensors, to create a smart home environment that can respond to the needs of its occupants automatically. In this instance, a microcontroller is employed as the control system, with sound sensors as input to drive other supporting devices (Mamahit et al., 2023).

Importance and Relevance

One example of the application of microcontroller technology that is widely used today is a sound-based home lighting control system. By using a sound sensor as input, this technology allows users to turn lights on or off with just a sound command, without having to approach a switch or other control device. The sound sensor detects sound waves in the surrounding environment, which are then translated by the microcontroller as a command to turn the lights on or off. The design of an automatic lighting system using a sound sensor is expected to be an innovative solution to create a smarter and more efficient home environment. This technology will not only make everyday life easier, but also be a reference for the development of the concept of a future home, where everything can be operated more easily and comfortably (Darma et al., 2024). This project provides a cost-effective solution for smart lighting. By using simple electronic components, it demonstrates how automation can improve daily life. The results of this study can be applied to homes, offices, and assisted-living facilities to increase comfort and accessibility. Finally, this research serves as a technical blueprint for future innovators and students, offering a foundation for further advancements in sensor-based smart home technologies.

Problem Statement

In an era where home automation is becoming a standard for modern living, traditional manual switches often fall short in providing the seamless experience required for efficiency and inclusivity. Despite the advancements in smart technology, several challenges remain regarding the reliability and practical application of hands-free controls. This study aims to address these gaps by investigating the effectiveness of a sound sensor–Arduino setup in controlling household appliances compared to traditional manual switches, focusing on convenience and responsiveness. Additionally, it examines the maximum effective detection range and coverage area of the sound sensor when placed within a room, as well as the limitations that affect the performance of a clap-based switching system, including sensitivity range, response delay, and susceptibility to false triggering.

General and Specific Objectives

The primary goal of this research is to develop a sound-responsive smart lighting solution, guided by several key objectives. The study aims to design a schematic and hardware framework that integrates sound sensors (microphones), microcontrollers, and LED lighting modules. It also seeks to evaluate the system's performance in various environments to determine the optimal sound frequency and decibel levels required for consistent activation. Furthermore, the research analyzes the practical benefits of the system, focusing on improved accessibility for individuals with limited mobility and its overall potential to reduce reliance on manual switches.

Scope and limitations

This study focuses on the design and development of a sound sensor–based lighting system using an Arduino microcontroller. The system is designed to detect sound signals, such as hand claps, and convert them into ON and OFF commands for controlling a low-power electrical load through a relay module. The project covers the

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basic hardware components, including the sound sensor module, Arduino Uno, relay, and indicator output, as well as the programming required to process sound input and trigger the switching action.

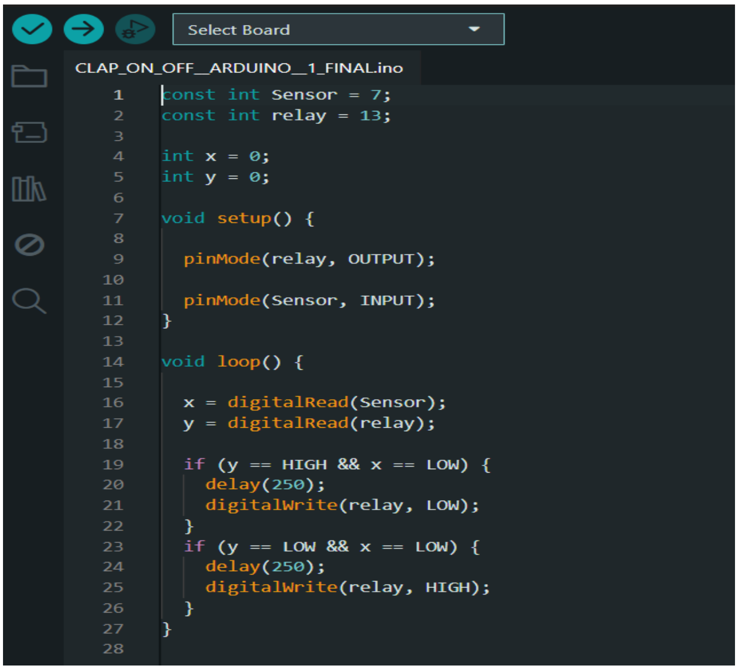
The study is limited to sound-based input only and does not include movements or mobile application control. The system is tested in a controlled indoor environment and may not perform accurately in areas with excessive background noise and within large coverage areas. In addition, the project is intended for demonstration and educational purposes and is not designed to handle high-voltage or high-current appliances beyond the relay's rated capacity.

METHODOLOGY

This study employed a prototype-based experimental method to demonstrate the integration of mixed signals and sensors through sound-actived lighting systems, specifically triggered by clapping. The sensor was designed using Proteus Professional 8, utilizing its Arduino stimulation environment. This was virtually assembled first using Arduino Uno R3 Atmega as the main microcontroller, an ACE6467 high sensitive microphone electret for sound detection, an ACE6363 5V 1A channel relay for load switching, a 220V light bulb voltage for lighting, and a male-to-female jumper wires for interconnections. The Arduino program was written and compiled using Arduino IDE (constructed code below) , then uploaded into Proteus simulation to enable using real time testing of sound detection.

The testing was conducted using 3 different methods, including single clap, snapping a finger, and tapping an object with 6 repeated testing each. A sound limit tolerance was applied to account variations in microphone sensitivity and background noise. The success criteria required accurate detection of clap sounds, proper activation of the relay module, and correct switching of the 220V light bulb without false triggering. All tests were executed without external respondents; the prototype was evaluated through internal testing and observation.

Figure 5. Arduino Source Code




```
const int Sensor = 7;
const int relay = 13;

int x = 0;
int y = 0;

void setup() {

  pinMode(relay, OUTPUT);

  pinMode(Sensor, INPUT);
}

void loop() {

  x = digitalRead(Sensor);
  y = digitalRead(relay);

  if (y == HIGH && x == LOW) {
    delay(250);
    digitalWrite(relay, LOW);
  }
  if (y == LOW && x == LOW) {
    delay(250);
    digitalWrite(relay, HIGH);
  }
}
```

It presents Arduino source code used in implementation of the sound activated lighting system. The program is responsible for reading the analog output of the sound sensor, processing the detected sound intensity, and comparing it against a predefined limit value. Once the sound level exceeds the set limit, the Arduino generates a digital control signal to activate the relay module, in that way switching the 220V light bulb on. If the detected sound remains below the limit, the relay remains deactivated and the light stays off. This code shows the conversion of the analog sensor into digital output control, highlighting the mixed-signal processing capability of the Arduino microcontroller.

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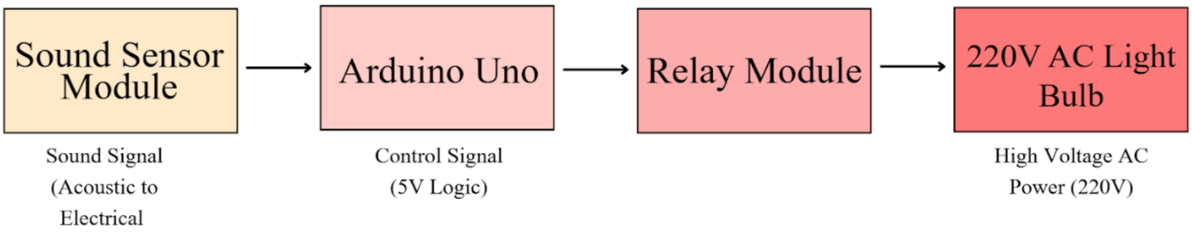
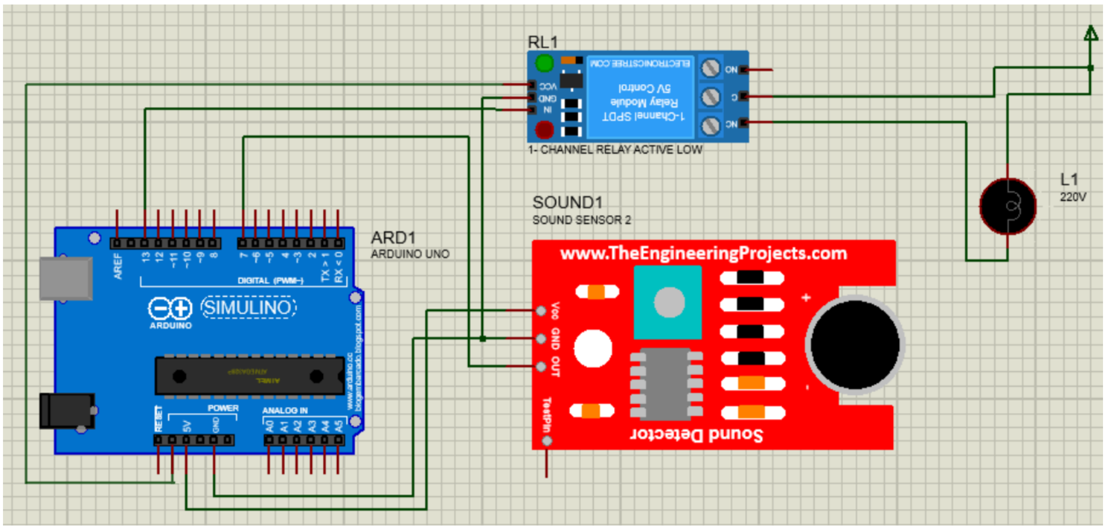
Figure 6. Block Diagram of Sound-Activated Light Control



It illustrates the block diagram of the prototype sound-activated lighting system, showing the overall structure and signal flow. The system begins with the sound sensor module, which is the microphone module, that detects acoustic signals such as clapping, snapping a finder, tapping an object, etc., and converts them into an electrical signal. This analog signal is sent to the Arduino Uno, which processes and evaluates based on a predefined limit. Upon detection of a valid sound input, the Ardctrically isolated switch, allowing low voltage control signals from the Arduino to safely activate the 220V AC light bulb. The block diagram highlights the integration of analog sensing and digital control, highlighting the mixed-signal nature of the system.

Figure 7. Schematic Diagram of Sound-Activated Light Control



It presents the schematic diagram of the sound-activated lightning system designed in Proteus Professional 8. The circuit consists of an Arduino Uno R3 microcontroller, which serves as the main control unit. An ACE6467 electret microphone is connected to the Arduino input pins to detect sound signals such as claps, snaps, or tapping.

The detected sound is processed by the Arduino based on a predefined limit. An ACE6363 5V 1A relay module is interfaced with the Arduino to safely control the high voltage load. When the relay is activated, it switches the 220V light bulb on, providing the system output. The schematic diagram illustrates the proper electrical connections and interaction between the input sensor, processing unit, switching device, and output load, ensuring correct and safe system operation. The proposed sound-activated lightning system is composed of the following hardware and software components. Each component plays a vital role in ensuring proper sensor detection, signal processing, and output control.

Arduino Uno R3 (ATmega38P) is microcontroller of the system. It processes the analog signal from the sensor, performs, performs limit-based decision making, and generates a digital output control to control the relay module. Sound Sensor (Electret High Sensitive Microphone Module – ACE6467) detects acoustic signals such as clapping, snapping a finger, tapping an object, etc., and converts sound waves into an electrical signal that can be read by the Arduino. Relay Module (ACE6363, 5V 1A Single-Channel) electrically isolated switch that allows the low voltage Arduino output to safely control a high voltage 220V AC light bulb. The 220V AC Light

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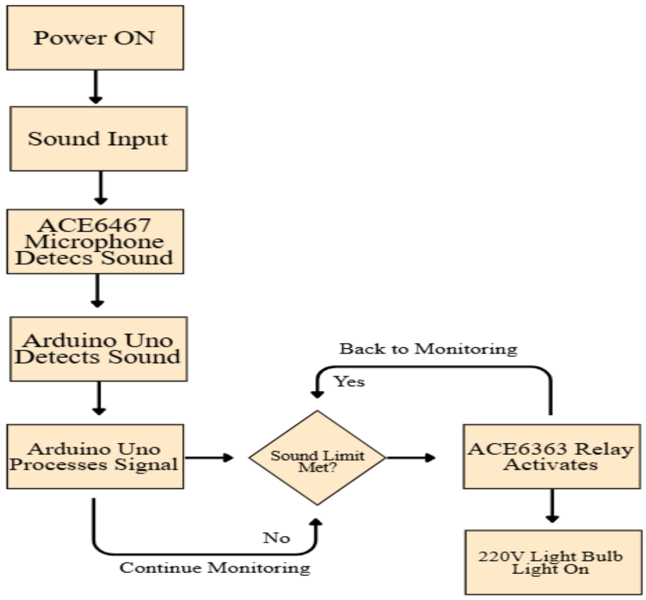
Bulb where the output device that turns on or off based on the activation of the relay module. A Male-to-Female Jumper Wires To connect the components and ensure proper signal and power transmission between modules.

Figure 8 . Flowchart and System Operation



It shows the system flowchart of the sound-activated lighting system. It describes the sequence of the system, starting from power initialization and continuous sound monitoring. The Arduino Uno R3 evaluates the detected sound input against the limit to determine system response. When the sound level meets the condition, the control signal is sent to activate the relay, which turns the light bulb on. If the condition is not, the system remains in a monitoring state. This flowchart highlights the decision-making process and logical flow of the system.

Tools & Software Used

The innovation and simulation of the sound-activated lighting system were conducted using Proteus Professional 8, which was used to design the schematic diagram and simulate the circuit operation. The software allowed real time testing of sound detection and relay switching behavior. The Arduino Integrated Development Environment (IDE) was used to write, compile, and upload the control program to the Arduino Uno R3 within the Proteus simulation. These tools enabled development testing and validation of the system.

Table 1. Variables and Conditions Used

Category	Tool / Software	Purpose / Function
Microcontroller	Arduino Uno R3 (ATmega328P)	Processes analog signals from the sound sensor, performs limit-based decision making, and generates digital output to control the relay module.
Sound Sensor	ACE6467 Electret High-Sensitivity Microphone Module	Detects acoustic signals such as claps, snaps, or tapping and converts them into electrical signals readable by the Arduino.
Relay Module	ACE6363 5V 1A Single-Channel Relay	Electrically isolates and allows the low-voltage Arduino output to safely control a high-voltage 220V AC light bulb.
Output Device	220V AC Light Bulb	Provides visual output based on relay activation (ON/OFF).

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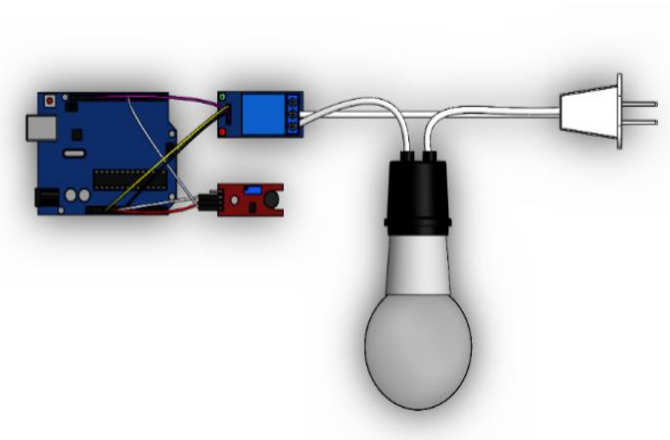
Connection Components	Male-to-Female Jumper Wires	Ensures proper electrical connections and signal/power transmission between modules.
Circuit Design & Simulation	Proteus Professional 8	Designs schematic diagrams, simulates circuit operation, and allows real-time testing of sound detection and relay switching.
Programming IDE	Arduino Integrated Development Environment (IDE)	Writes, compiles, and uploads the control program to the Arduino Uno; enables simulation within Proteus.
3D Modeling & Assembly Visualization	SolidWorks	Provides top-view assembly design for component arrangement and practical visualization of the system layout.

Development & Implementation Steps

The system was developed by first connecting the sound sensor to the Arduino Uno R3 with GND to GND, VCC to 3.3V, and the digital output to pin 7. The relay module was then connected with GND to GND, VCC to 5V, and its control input 13. After completing the hardware connections, the control program was uploaded using the Arduino IDE, and the complete circuit was stimulated in Proteus Professional 8 to verify sound detection.

Figure 9. Actual Picture of Sound Activated Lighting System

Figure 10. SolidWorks Assembly



It illustrates the top view SolidWorks assembly design of the sound activated lighting system. The assembly illustrates the arrangement and placement of the system components as viewed from above, providing a clear presentation of the overall layout. This top view model was created to visualize component positioning organization, supporting the practicality of the system implementation.

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RESULTS & DISCUSSION

The testing part was done to see how well the Sound-Responsive Smart Lighting System works. This system uses a sensor and an Arduino Uno. Testing was conducted inside a quiet indoor environment to ensure that external noise did not affect the result. Prior to the testing process, all system components were properly connected and the program was successfully uploaded to the Arduino Uno. This procedure ensured that the Sound-Responsive Smart Lighting System Functioned correctly with the sound sensor and the Arduino Uno.

The light was tested using a single clap sound to toggle the light either ON or OFF. Each test was performed at different distances between the sound source and the sensor to determine the effective operating range of the system. The tests started at a short distance and gradually increased until the sensor could no longer detect the clap sound. Each distance was tested multiple times to ensure consistency and accuracy of the result. After using the clap sound as input, the researchers tested the system using snap and tapping input as well to see if it works the same as the clap input.

Table 2. System for experimental control with a 2-meter maximum range using clap sound

Test No.	Initial State of the Light	Distance from Sensor	Clap input	Final State of Light	Result
1	ON	0.5m	1 clap	OFF	Excellent
2	OFF	0.5m	1 clap	ON	Excellent
3	ON	1.0m	1 clap	OFF	Excellent
4	OFF	1.0m	1 clap	ON	Excellent
5	ON	2.0m	1 clap	OFF	Excellent
6	OFF	2.0m	1 clap	ON	Excellent

Table 3**.** System for experimental control with a 2-meter maximum range using snap sound

Test No.	Initial State of the Light	Distance from Sensor	Snap input	Final State of Light	Result
1	ON	0.5m	1 snap	OFF	Excellent
2	OFF	0.5m	1 snap	ON	Excellent
3	ON	1.0m	1 snap	ON	Poor
4	OFF	1.0m	1 snap	OFF	Poor
5	ON	2.0m	1 snap	ON	Poor
6	OFF	2.0m	1 snap	OFF	Poor

Table 4. System for experimental control with a 2-meter maximum range using tapping an object

Test No.	Initial State of the Light	Distance from Sensor	Tap input	Final State of Light	Result
1	ON	0.5m	1 tap	OFF	Excellent

2	OFF	0.5m	1 tap	ON	Excellent
3	ON	1.0m	1 tap	ON	Poor
4	OFF	1.0m	1 tap	OFF	Poor
5	ON	2.0m	1 tap	ON	Poor
6	OFF	2.0m	1 tap	OFF	Poor

Table 5. Testing Discussion of the Clap-Controlled Smart Lighting System

1	During the first test, the light was initially in the ON state and positioned at a distance of 0.5 meter from the sound sensor. When a single clap was produced, the system successfully detected the input and turned the light OFF. This result indicates that the system responds correctly to clap input at close distances.
2	During the second test, the light was initially in the OFF state and positioned at a distance of 0.5 meter from the sound sensor. When a single clap was produced, the system successfully detected the input and turned the light ON. This result indicates that the system responds correctly to clap input at close distances.
3	During the third test, the light was initially in the ON state and positioned at a distance of 1.0 meter from the sound sensor. When a single clap was produced, the system successfully detected the input and turned the light OFF. This result indicates that the system continues to function effectively to a moderate distance.
4	During the fourth test, the light was initially in the OFF state and positioned at a distance of 1.0 meter from the sound sensor. When a single clap was produced, the system successfully detected the input and turned the light ON. This outcome confirms consistent system performance at a distance of 1.0 meter.
5	At a distance of 2.0 meters, the light was initially in the ON state. When a single clap was produced, the system successfully detected the sound input and turned the light OFF. This result shows that the system remains responsive at its maximum effective operating range.
6	For the final test, the light was initially in the OFF state and positioned 2.0 meter away from the sound sensor. Upon producing a single clap, the system detected the sound input and turned the light ON. This confirms that the system operated effectively up to a distance of 2.0 meters.

Analysis and Interpretation

The Sound-Responsive Smart Lighting System worked properly during the testing process. The system was able to turn the light ON and OFF using a single clap sound. The clap sound was detected at a distance of 0.5 meters, 1.0 meter, and up to 2.0 meters. This shows that the sound sensor and the Arduino Uno functioned correctly during testing.

The test result also shows that the system worked correctly regardless of the initial state of the light. Whether the light was initially ON or OFF, one clap was enough to change its state. This indicates that the program uploaded to the Arduino Uno worked as intended. As a result, the light could be controlled without using hands, as described in the system design.

Distance was identified as an important factor affecting system performance. The system continued to work properly at distances of up to 2.0 meters. When the clap sound was produced beyond 2.0 meters, the sensor was no longer able to detect the sound, and the light did not respond. This limitation is due to the capability of the sound sensor, as discussed in the system description.

Environmental conditions also affected system performance. Testing conducted in a quiet indoor environment resulted in accurate sound detection and stable system response. This shows that background noise can affect the sensor's ability to detect sound, making controlled testing conditions important.

The observations and analysis confirms that the Sound-Responsive Smart Lighting System performs effectively within its intended range and design parameters. The system provides a convenient and efficient alternative to traditional manual switches by allowing hands-free control through clap detection. However, the system's performance is limited by the sound detection range of the sensor and the presence of environmental noise, which may affect detection accuracy.

Problems Encountered & Solutions

When the Sound-Responsive Smart Lighting System was tested, several issues were observed. These problems were related to the known limitations of the system, such as sensor sensitivity, limited detection range, and the detection of unwanted sounds. These limitations affected the overall performance of the system during testing.

One major issue encountered was false triggering of the sound sensor. The sensor sometimes detected unwanted noises such as finger snapping, tapping on objects, and background sounds instead of the intended clap sound. This issue was more noticeable at distances of 1.0 meter and 2.0 meters, where the sensor became more sensitive to surrounding noise. Because of this, the light did not always respond correctly. In some cases, the light turned ON or OFF unexpectedly, while in other cases, it failed to respond to the clap input

Another problem involved the sensitivity setting of the sound sensor. When the sensitivity was set too low, the sensor was unable to detect the clap sound. As a result, the system did not respond, especially when the clap was produced at a farther distance. To resolve this issue, the sensitivity of the sound sensor was increased to ensure that the clap sound could be properly detected and that the system functioned as intended.

The system also showed a limitation in sound detection range. It was observed that the system worked properly only when the clap sound was produced within 2.0 meters of the sensor. When the clap was made beyond this distance, the sensor failed to detect the sound and the light did not respond. This limitation is due to the capability of the sound sensor used in the system.

CONCLUSION

An Arduino-based microcontroller can effectively bridge the gap between standard manual switches and automated home technology, as demonstrated by the development of the Sound-Responsive Smart Lighting System. The researchers conclude that integrating an Arduino Uno, Sound Sensor, and Relay Module is a highly effective way to control lights through acoustic impulses based on their experimental testing and analysis. By providing a hands-free substitute for manual switching, the system fulfilled its main goal and immediately met the demands of individuals with limited mobility. Based on the testing and analysis, the system performed most reliably when activated by a single clap, consistently delivering "Excellent" results up to a distance of 2.0 meters. These findings are supported by Wanda and Mubarak (2024), who noted that sound-based automation is a reliable alternative to traditional switches in modern living environments.

However, the study found that other sounds, such as tapping or snapping, significantly reduced the system's performance. This observation aligns with the research of Fauziah (2022), who emphasized that sound-responsive devices must be specifically calibrated to distinguish intentional triggers from environmental noise. Furthermore, environmental noise and sensor sensitivity settings were critical determinants; too much background noise may cause a false triggering or a failure to respond, highlighting the current need for controlled, quiet surroundings for accurate results. Ultimately, this research offers a technical blueprint for cost-effective smart home technology that reduces the need for manual switches and encourages energy-efficient living.

RECOMMENDATIONS

Further reliability and functionality of the Sound-Responsive Smart Lighting System are needed for its improvement. First, to reduce the false triggering seen during testing, it is recommended to incorporate a more advanced sound-processing algorithm or high-sensitivity microphone to better discern between deliberate claps and background noise, such as conversation or object tapping. Following the methodology in the research by Fauziah (2022), future iteration should concentrate on improving the FC-04 sensor's frequency detection to guarantee that the relay only activates for particular acoustic signals. In order to allow deployment in commercial spaces or larger rooms, future researchers should also look into ways to increase the effective detection range beyond the 2.0-meter restriction.

Most importantly, the project is not just limited to clapping; it may also have an additional speech command and another sound command system. While a multi-sound command system might be programmed to differentiate between various rhythmic patterns, like double-snaps or whistles, to independently control numerous lighting zones, a specific voice recognition module would enable the system to interpret certain spoken triggers. Furthermore, as proposed by Jiang (2024), the integration of a light-dependent resistor (LDR) is highly recommended to ensure the lighting system only activates during nighttime or low-light conditions, maximizing energy efficiency. Additionally, the system should be tested in more diverse and noisy real-world environments—such as busy offices or kitchens—to determine the optimal sensitivity thresholds required for practical use. For high-voltage household appliances, it is recommended to upgrade the relay capacity to safely manage larger appliances beyond the current demonstration approach, such as adding motion sensors as discussed in the study by García-Moreno et al. (2025), would create a more robust energy-saving environment by ensuring lights only activate when a room is actually occupied.

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