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Implementation of a Sound Sensor-Based Automatic Light Switch Using a Wemos D1 R32 Microcontroller in a Classroom

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Abstract− The development of Internet of Things (IoT) technology and intelligent control systems has encouraged the use of microcontroller devices to support energy efficiency and comfort in learning environments. One of the problems often encountered in classrooms is the use of inefficient lights, such as lights left on even when not in use or late turning off the lights after learning activities are finished. This study aims to design and implement a sound sensor-based automatic light switch system using a Wemos D1 R32 microcontroller in a classroom. This system is designed to detect certain voice commands, such as clapping or sound intensity at a certain threshold, which are then processed by the microcontroller to control the condition of the lights (on or off). The research method used is Research and Development (R&D), which includes the stages of needs analysis, system design, hardware and software development, testing, and system performance evaluation. The sound sensor is used as the main input to detect audio signals from the environment, while the Wemos D1 R32 functions as a control center that processes data and activates relays as light switches. The test results show that the system is able to respond to voice commands with a good success rate in relatively normal classroom environmental conditions. The implementation of this system contributes to increasing the efficiency of electrical energy use in classrooms and provides convenience for users without having to directly contact manual switches. Furthermore, this system also supports technology-based learning concepts and can be used as a practical learning medium for students in electronics and IoT. Therefore, the implementation of a sound sensor-based automatic light switch using the Wemos D1 R32 is expected to be an innovative solution for managing educational facilities more intelligently and sustainably.

Keywords: Sound Sensor; Automatic Light Switch; Wemos D1 R32; Internet of Things; Energy Efficiency

1. INTRODUCTION

The development of information and communication technology in recent years has spurred the emergence of various Internet of Things (IoT)-based innovations applied to building environments, including educational facilities. IoT enables physical devices such as sensors, actuators, and microcontrollers to connect and exchange data in real time, creating intelligent, adaptive, and efficient systems (Chen et al., 2021). One widely developed IoT application is lighting automation systems, which aim to reduce electrical energy waste while improving user comfort (Hidayat & Prakoso, 2025).

Classrooms are one of the areas with relatively high levels of electrical energy consumption, particularly from the use of lights that are on during operating hours. A common problem is that lights remain on even when the room is not in use or are turned off too late after teaching and learning activities have concluded. This condition is largely due to the reliance on manual switches, which are highly dependent on user awareness and discipline (Wang et al., 2022). Therefore, an automated lighting control system that can operate independently without direct physical interaction is needed.

Various studies have shown that IoT-based automated lighting systems can provide significant energy savings. The integration of sensors and microcontrollers in lighting systems can adjust lighting conditions to meet the actual needs of the room (Zhang et al., 2022). The implementation of smart lighting in educational buildings not only impacts energy efficiency but also improves the quality of the learning environment (Nguyen et al., 2024). With optimally controlled lighting, teaching and learning activities can be more comfortable and productive.

A microcontroller acts as the control center in lighting automation systems. One of the most widely used microcontrollers today is the ESP32 due to its high performance, low power consumption, and support for Wi-Fi and Bluetooth connectivity (Rahman et al., 2021). The Wemos D1 R32 is an ESP32-based development board compatible with the Arduino IDE, simplifying the design and development of automation systems. These advantages make the Wemos D1 R32 highly suitable for IoT applications in educational environments (Putra & Nugroho, 2022).

In addition to microcontrollers, selecting the right sensor also significantly determines the performance of an automation system. A sound sensor is one type of sensor that can be used as an input for automatic lighting control. This sensor works by detecting sound intensity in the surrounding environment and converting it into an electrical signal that can be processed by a microcontroller (Lumbantobing, 2022). The use of sound sensors offers the advantage of easy, touch-free operation, making it more practical and hygienic, especially in classrooms used by many people (Alam & Ali, 2021).

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Several studies have examined the use of voice control in building automation systems. One study developed an IoT-based automation system with voice commands to control electrical devices in homes and buildings (Kumar & Singh, 2021). An ESP32-based voice control system was able to operate with a high level of responsiveness in controlling electrical devices (Surani et al., 2022). The integration of speech recognition with automation systems can improve user comfort and system flexibility (Hossain et al., 2023).

In the educational context, the concept of a smart classroom is increasingly being developed in line with the need for a modern and efficient learning environment. Smart classrooms utilize IoT technology to manage various aspects of a classroom, such as lighting, temperature, and multimedia devices (Saha et al., 2021). The application of IoT in classrooms can support technology-based learning processes and provide a more interactive learning experience for students (Siregar & Ramadhan, 2023).

However, implementing voice control systems in classrooms presents its own challenges. Classroom environments tend to have varying noise levels due to student activity, potentially leading to incorrect voice detection. One of the main challenges in voice control systems is determining the appropriate sound threshold to prevent the system from responding to unwanted sounds (Kaur & Kaur, 2023). Therefore, testing the system in real-world environments is crucial.

Previous research has focused largely on the use of motion sensors or light sensors to trigger automated lighting systems. However, the use of voice sensors as automatic light switches is still relatively limited, particularly in classroom environments (Prasetyo & Wibowo, 2023). Voice assistant-based lighting control has great potential for development, but requires adjustments to operate optimally in environments with certain noise levels (Rasuli et al., 2023). Selecting the right hardware and system parameters is crucial for implementing classroom automation (Arifin & Maulana, 2024).

Beyond technical aspects, implementing a lighting automation system is also related to energy efficiency and environmental sustainability. IoT-based energy management systems can significantly reduce electricity consumption in educational buildings (Singh & Verma, 2024). Integrating voice interfaces into smart lighting systems can improve the effectiveness of lighting control while supporting the concept of sustainable smart buildings (Lee et al., 2025).

Based on the description, it can be concluded that the implementation of a sound sensor-based automatic light switch using the Wemos D1 R32 microcontroller has great potential to improve energy efficiency and comfort in classrooms. This study aims to design, implement, and evaluate the performance of the system in real classroom conditions. By utilizing the Research and Development (R&D) method, this study is expected to produce a system that is applicable, effective, and easy to develop further as part of the implementation of an IoT-based smart classroom.

2. RESEARCH METHODOLOGY

The research method used in this study was Research and Development (R&D). This method was chosen because the aim was to produce a product in the form of an automatic light switch system and test its effectiveness and performance. The R&D research stages included needs analysis, system design, development, testing, and evaluation.

2.1 Needs Analysis

During the needs analysis stage, problems in the classroom related to lighting usage and user needs for an automation system were identified.

2.2 System Design

The system design stage included hardware and software design. The hardware consisted of a Wemos D1 R32, sound sensor, relay module, lights, and a power supply. The software was developed using the Arduino IDE using the C/C++ programming language.

2.3 System Development

The development stage involved assembling all hardware components according to the design and uploading the program to the microcontroller.

2.4 System Testing

Next, the system was tested to determine the sensor's ability to detect sound and the system's response in controlling the lights. Testing was conducted in several different classroom environments.

2.5 System Evaluation

The evaluation phase involves analyzing test results to determine the system's success rate, reliability, and potential for further development. Test data is analyzed descriptively to provide an overview of the system's overall performance.

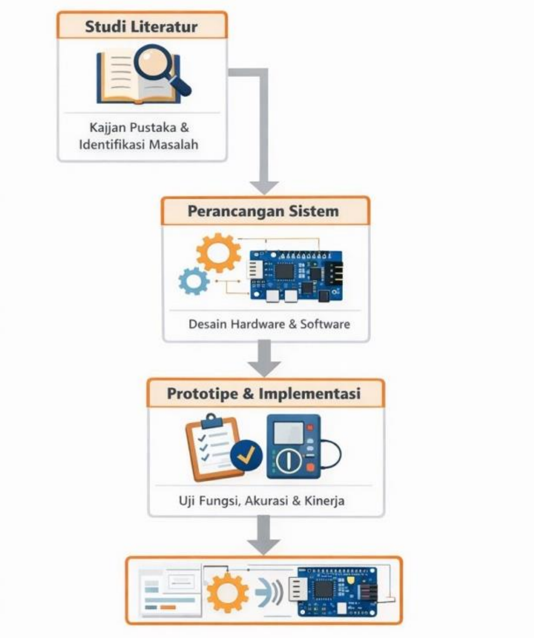

Figure 1. Research Flow

Figure 1 Research flow for implementing a sound sensor-based automatic light switch system.

3. RESULTS AND DISCUSSION

This automatic light switch based on a sound sensor illustrates how sound in a classroom is processed to automatically control the lights using the Wemos D1 R32 as a control center.

3.1 System Design and Development

1. Sound Source (Classroom Environment)

The flow begins with a sound source originating from the classroom environment, such as:

- Applause
- Voice commands
- Sounds with a certain intensity

This sound is the initial trigger for the system to operate.

2. Sound Sensor

The sound generated in the classroom environment is then captured by the sound sensor. The function of the sound sensor in this system is:

- Detecting sound intensity
- Converting sound waves into electrical signals (analog/digital)

The sensor will only send a signal if the received sound exceeds a predetermined threshold.

3. Wemos D1 R32 (Microcontroller)

The signal from the sound sensor is then sent to the Wemos D1 R32 as the system's processing center.

At this stage, the Wemos D1 R32 performs several key processes:

- Reading signal data from the sound sensor
- Comparing the sound value to the threshold
- Making a decision:
  - If the sound is valid → the system is active
  - If the sound is invalid → the system does not respond

This control logic is programmed using the Arduino IDE.

4. Relay Module

If the Wemos D1 R32 determines that the received sound is valid, the microcontroller will:

- Sends control signals to the relay module

The functions of the relay module are:

- Acts as an electronic switch
- Connects or disconnects AC power to the lamp
- Isolates the low-voltage circuit (microcontroller) from the high-voltage circuit (lamp)

5. Lamp (Load)

The final stage of the system flow is the lamp as the output load.

- If the relay is active (ON) → the lamp is on
- If the relay is inactive (OFF) → the lamp is off

Thus, the lamp's condition is completely controlled by the sound processing results in the microcontroller.

6. LCD as Information Media

During system development, an LCD was added to directly display system condition information, such as:

- Lamp status (ON/OFF)
- Automatic system status

The LCD provides visual feedback to the user so that system conditions can be known without having to directly observe the lamp.

7. Wi-Fi-Based Real-Time Monitoring

One of the main developments in this system is real-time monitoring via a Wi-Fi connection. Through this feature:

- Light status can be monitored via other devices such as laptops or smartphones
- System condition information can be accessed online
- The system supports the Internet of Things (IoT) concept

This feature allows the system to be further developed into an integrated smart classroom application.

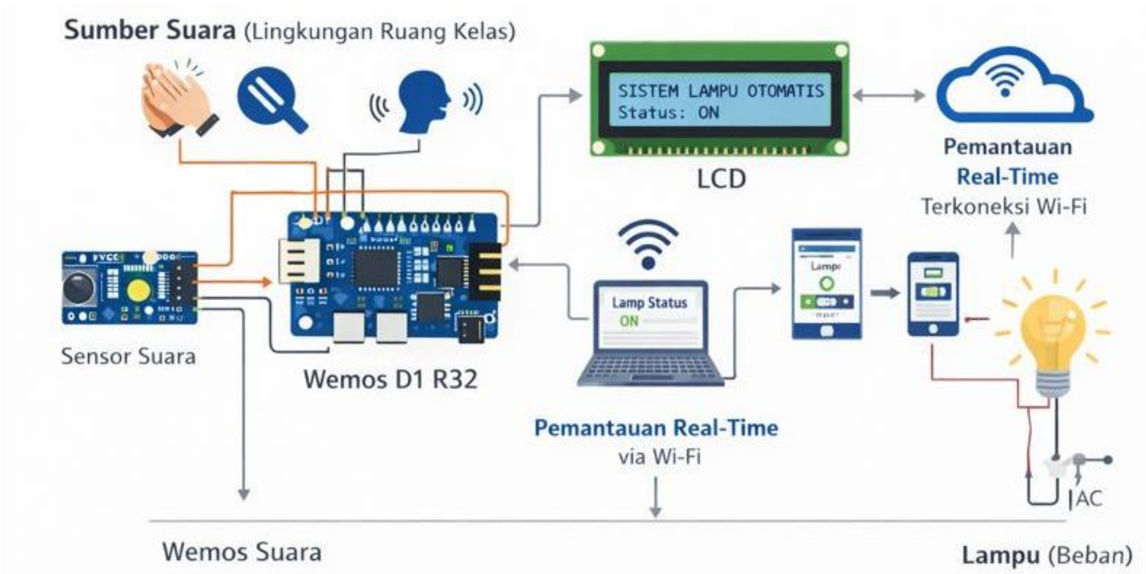

Figure 2. Development of an Automatic Light Switch System Based on a Sound Sensor

Figure 2 depicts an automatic light switch system based on a sound sensor that not only functions as a light controller but has also been developed with monitoring and information display features. This system was designed using a Wemos D1 R32 microcontroller as the main control center.

3.2 System Testing

System testing was conducted to determine the performance, reliability, and success of the automatic light switch system based on a sound sensor using a Wemos D1 R32 microcontroller. This testing aimed to ensure that each system component functioned according to its designed function and that the system operated optimally in real-world classroom conditions.

Table 1. Sound Source Distance Testing

Distance (meters)	Sound Detection	System Response	Light Condition
1	Detected	Fast	Normal ON/OFF
2	Detected	Normal	Normal ON/OFF
3	Detected	Slightly Slow	Normal ON/OFF
>3	Unstable	Inconsistent	Unstable

Based on the test results, several important findings were obtained:

- The system was able to detect sound with a good success rate at distances of 1–3 meters.
- The system's response time was relatively fast and did not disrupt user activities.
- The system was stable during repeated operation.
- The sensor threshold setting significantly affected system accuracy.

Accuracy testing was conducted to determine the system's success rate in responding to voice commands at various sound source distances. Each test scenario was carried out 10 times, then calculated.

Table 2. System Accuracy Testing Based on Distance

Sound Source Distance (m)	Number of Trials	Success	Fail	Accuracy (%)
1	10	10	0	100%
2	10	9	1	90%
3	10	8	2	80%
>3	10	5	5	50%

Based on the results of the system accuracy test based on distance:

- At a distance of 1 meter, the system demonstrated the highest accuracy of 100%, meaning all voice commands were successfully recognized.
- At a distance of 2 meters, the system accuracy decreased slightly to 90%, but was still considered very good.
- At a distance of 3 meters, accuracy decreased to 80%, indicating the effect of distance on the sensitivity of the sound sensor.
- At distances greater than 3 meters, accuracy dropped significantly to 50%, due to the weakening of sound intensity and increased noise interference.

These results indicate that the system operates optimally at a distance of 1–3 meters, so the placement of sound sensors in classrooms must take this range into account for optimal system performance.

3.3 System Evaluation

Test results indicate that the automatic light switch system based on sound sensors using the Wemos D1 R32 functions as designed. However, there are several areas that require further development, such as:

- Adjusting the sensor threshold in high-noise environments.
- Adding a sound filter to improve detection accuracy.
- Integrating the system with web-based or mobile monitoring applications.

4. CONCLUSION

This research successfully designed and implemented an automatic light switch system based on a sound sensor using a Wemos D1 R32 microcontroller applied to a classroom. The developed system is able to control lights automatically based on voice commands, thereby increasing the efficiency of electrical energy use and making it easier for users to operate room lighting without physical contact. Based on the results of the tests that have been carried out, the system shows good performance at a sound source distance of between 1 and 3 meters with an accuracy level reaching 80%–100%. At this distance, the sound sensor is able to detect commands with a fast and stable response. However, at a distance of more than 3 meters, the accuracy level decreases significantly due to reduced sound intensity and the presence of environmental noise interference. This indicates that distance and environmental conditions are important factors that affect system performance. The test results also prove that the integration between the sound sensor, relay module, and Wemos D1 R32 can run optimally and synchronously. The microcontroller is able to process input signals from the sound sensor and control the relay output to turn the lights on or off according to the given command. Thus, the designed system has met the research objectives, namely to produce a lighting automation device that is simple, effective, and easy to implement in educational environments. Overall, the implementation of this automatic light switch based on a voice sensor is a viable alternative solution to support the smart classroom concept and save electricity. This system also has the potential for further development with additional features such as artificial intelligence-based voice recognition, Internet of Things (IoT) connectivity, and integration with other smart devices to increase the system's reliability and flexibility in the future.

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