Automatic Lighting System using ESP32 and Sound Detection for Energy Efficiency

Final Project

By:
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**Electronics Manufacturing Engineering
Study Program
Electrical Engineering Department
Politeknik Negeri Batam**
2025

Statement of Authenticity of Final Project

I, the undersigned, hereby declare that the contents of my final project, either in part or in whole, titled: "Automatic Lighting System Using ESP32 and Sound Detection for Energy Efficiency" are entirely my own original intellectual work, completed without the use of unauthorized materials and are not the work of others that I claim as my own. All references cited or referenced have been fully listed in the bibliography. If it is proven that my statement is untrue, I am willing to accept sanctions in accordance with applicable regulations.

Batam, 08 August 2025

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Approval sheet

The Final Project is structured to fulfill one of the requirements for obtaining a degree
Bachelor of Associate Engineer (AMd.T.)
in
Batam State Polytechnic

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Session date: 08 08, 2025

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Abstract

This study designs and implements an automatic lighting system based on the ESP32 microcontroller and sound sensors to improve energy efficiency. The lights will only turn on when sound is detected in the environment, thereby reducing electricity consumption. The system is integrated with an Internet of Things (IoT) platform, enabling users to monitor the status and control the lighting remotely via a mobile application. The hardware was designed using Fritzing, while the software was developed with the Arduino IDE. Test results indicate that the system operates efficiently, responsively, and is easy to use, making it suitable for application in smart homes or public spaces to enhance comfort, security, and energy savings.
Keywords: ESP32, IoT, Automatic Lighting, Energy Efficiency, Sound Detection

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The author fully realizes that this report is far from perfect. Therefore, constructive criticism and suggestions are greatly appreciated for future improvements. Finally, the author hopes that this Final Project Report will be useful to readers and make a meaningful contribution to the world of industry and education.

Batam,08 August 2025

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Automatic Lighting System using ESP32 and Sound Detection for Energy Efficiency

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Abstract—**This study designs and implements an automatic lighting system based on the ESP32 microcontroller and sound sensors to improve energy efficiency. The lights will only turn on when sound is detected in the environment, thereby reducing electricity consumption. The system is integrated with an Internet of Things (IoT) platform, enabling users to monitor the status and control the lighting remotely via a mobile application. The hardware was designed using Fritzing, while the software was developed with the Arduino IDE. Test results indicate that the system operates efficiently, responsively, and is easy to use, making it suitable for implementation in smart homes or public spaces to enhance comfort, security, and energy savings.**

Keywords: ESP32, IoT, Automatic Lighting System, Energy Efficiency, Sound Detection

1. Introduction

With the development of Internet of Things (IoT) technology, the creation of microelectronics-based smart control systems for energy efficiency has become increasingly vital. Lighting systems have traditionally been a source of energy waste, especially when lights are left on without any user activity [1][2]. Therefore, research on smart lighting systems has begun to be developed using various sensor approaches, optimization algorithms, and IoT connectivity [2].

The ESP32 microcontroller is a popular choice in the development of such systems due to its low cost, efficiency, and full integration with Wi-Fi and Bluetooth features [3]. In several studies, ESP32 was used to control lighting in real time through a web-based monitoring system and application [4]. or in a smart home system with remote control using the Blynk app [5]. In addition, non-voice sensor-based approaches such as fuzzy logic to adjust lighting levels based on natural light intensity have also been researched, with potential energy savings of up to 93% [1]. In the context of indoor farming, IoT-based light control systems have also been shown to significantly save energy [6].

The integration of voice detection as a trigger for automation is becoming increasingly popular. For example, home automation systems with offline voice control based on TinyML offer high accuracy, low latency, and energy efficiency without dependence on the cloud [7][8]. A similar approach is also applied in offline smart home automation systems to improve performance and sustainability [2].

In the industrial sector, IoT lighting systems with optimization algorithms (such as simplex) and presence sensors have successfully reduced power consumption by up to 80% in office environments [2]. Meanwhile, the use of ESP32 in daily power consumption monitoring systems has also proven to be reliable. [9]. In renewable energy-based applications, the integration of ESP32 for solar home efficiency shows promising results in energy efficiency[10]. In general, these studies show that IoT- and sensor-based automatic lighting systems, including sound, offer significant benefits in terms of energy efficiency, ease of use, and environmental adaptability. However, research combining the application of ESP32 with sound detection as the main trigger and IoT integration for remote monitoring is still relatively scarce, especially in practical contexts such as smart homes and public spaces.

Therefore, this study aims to fill this gap by designing and lighting system that uses ESP32 and sound sensors as the main triggers. The system will be integrated with an IoT platform so that users can monitor and control the lights remotely via a mobile app. Performance evaluation includes responsiveness, energy efficiency, and ease of use, making it a practical and energy-efficient implementing an automatic solution for smart homes and public spaces. [11].

2. Methode

A. *Research Steps*

The research began with a literature study, followed by the design of hardware, software, and mechanics. After that, the system was implemented and the lamp functions were tested. If it was not suitable, improvements were made and retested. If it was suitable, it proceeded to data collection, analysis, and evaluation until a final conclusion was reached. The flowchart shows the sequence of this process from Start to End using standard symbols.

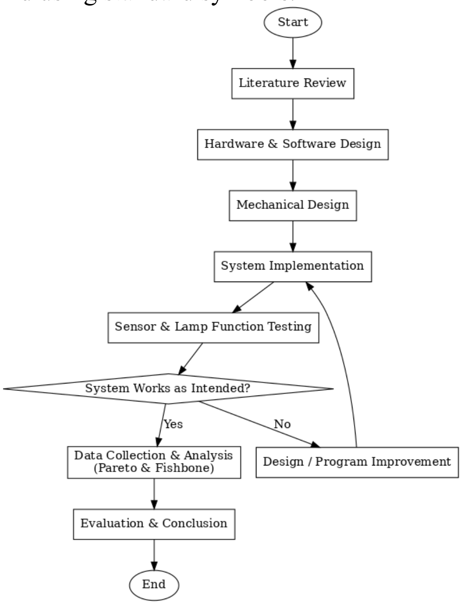

Figure. 1. Research method flowchart

The research process began with a literature study to gather theoretical foundations and previous research results related to automatic lighting systems, ESP32, IoT, and sound detection. The next stage was the design of hardware and software, including circuit design using Fritzing and programming in Arduino IDE, as well as the creation of a container at the mechanical design stage.

Next, the system was implemented by assembling the hardware and uploading the program to the ESP32, then tested at the sensor and light function testing stage. At the decision point, it is determined whether the system is functioning as intended. If not, design or program modifications are made and the system is reimplemented. If it is functioning as intended, the process continues with data collection and analysis using Pareto and Fishbone diagrams. The final stage is evaluation and conclusion, which summarizes the research findings and assesses the system's performance.

3. RESULT AND DISCUSSION

A. Poduct Deficiencies

This automatic lighting system is designed to improve safety and visibility in the workplace, creating a modern and professional impression. With the integration of ESP32 and Blynk, users can control the lights remotely using their smartphones, providing flexibility and convenience. In addition, this system also focuses on energy efficiency to support environmentally friendly efforts. Therefore, the system design will implement all of these features optimally.

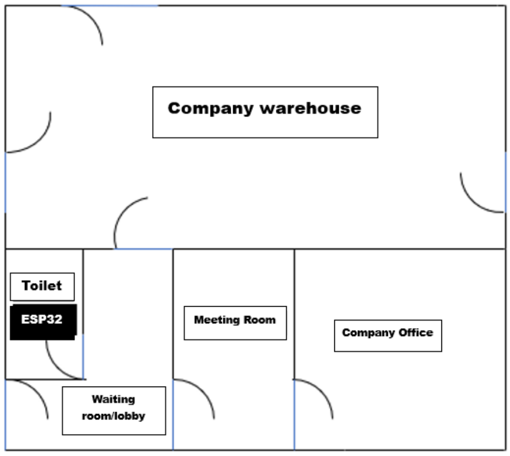

Figure. 2.Esp322 Layout

B. System Test Results

Testing was conducted to ensure that the ESP32-based automatic lighting system and sound sensor functioned as designed, both in automatic and manual modes. In automatic mode, the lights turn on when sound is detected and automatically turn off if no sound is detected within 10 minutes. This auto-off feature is designed to conserve electricity.

The testing method was carried out by providing stimuli in the form of hand clapping or loud noises at different distances, and observing the system's response until the auto-off feature was activated. In manual mode, the lights were controlled remotely via the Blynk IoT app, without the influence of auto-off.

TABLE I
SOUND SENSOR RESPONSE TEST RESULTS

No	TEST SCENARIO	DISTANCE (M)	LIGHT RESPONSE TIME (SECONDS)	Auto-Off 10 Minutes Without Sound	Final Light Status
1	Clapping	1	0.8	Active	Off
2	Clapping	2	0.9	Active	Off
3	Loud sound	3	1.0	Active	Off
4	No sound from the start	-	-	-	Off
5	Loud sound followed by silence < 10	2	0.9	Inactive	on

Based on test results, the automatic mode is able to respond to sound in ≤ 1 second. The auto-off feature works as intended, turning off the light after 10 minutes without sound.

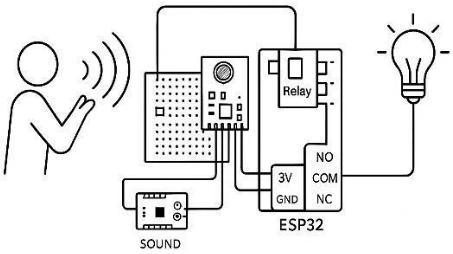

Figure. 3. Sound Sensor Testing Documentation (Automatic Mode)

Manual mode testing was conducted using the Blynk IoT application. The results showed an average response time of 0.7 seconds from the command in the application to the light turning on or off. Manual mode ignores the auto-off function.

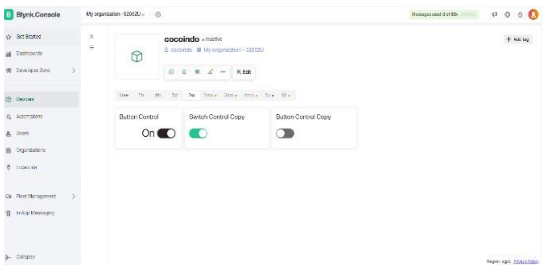

Figure. 4. Blynk IoT Application Display During Manual Control

This app makes it easy to control lights from anywhere as long as the device is connected to the internet. A comparison of response times between automatic and manual modes can be seen in Figure 4**.**

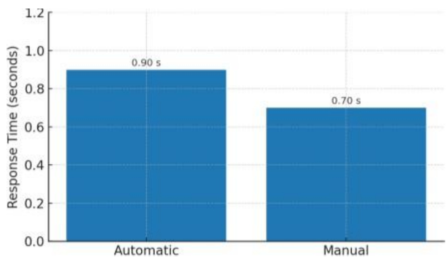

Figure. 5. Comparison Chart of Automatic and Manual Response Times

This difference shows that although manual mode is slightly faster, automatic mode provides energy efficiency through the auto-off feature. The auto-off feature was tested to observe the time it took for the lamp to turn off after 10 minutes of silence. The results of the observation are shown in Figure 5.

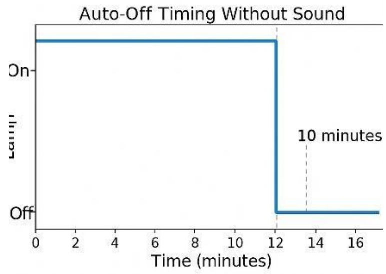

Figure. 6. Comparison Chart of Automatic and Manual Response Times

This feature works well and is a major factor in saving energy in the system..

CAnalisis Efisiensi Energi

Energy efficiency testing was conducted within the company to measure the amount of electricity savings generated by the ESP32-based automatic lighting system and sound sensors, compared to conventional manually controlled lighting systems.

The test was conducted in one of the company's work areas, which has varying levels of activity throughout the day. The reason for choosing this location was to observe the performance of the auto-off system in real working conditions, where lights are often left on even when there is no activity in the area. Measurements were taken using a digital wattmeter that recorded the total power consumption during the company's operating hours under two conditions:

- **No Automatic System** → Lights are controlled manually by the operator without an auto-off feature.
- **Automatic System** → Lights are controlled by a sound sensor and turn off automatically after 10 minutes without sound or activity.

Measurements were taken over five consecutive working days with normal schedules and workloads.

TABLE 2
COMPARISON OF DAILY POWER CONSUMPTION

No	SYSTEM CONDITION	AVERAGE POWER CONSUMPTIO N (WH/DAY)	ENERGY DEVELOPME NT (%)
1	Without an Automated System	120	-
2	With the System	75	37,5

Based on Table 2, the implementation of the automatic system resulted in energy savings of 37.5%. These savings were generated by the auto-off feature, which turns off the lights when the work area is not in use.

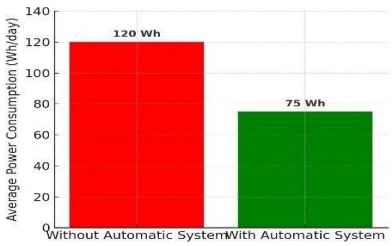

Figure. 6. Daily Power Consumption Comparison Chart

The graph shows that even though daily lighting usage patterns are similar, the automatic system provides significant savings thanks to its auto-off feature. This demonstrates that the system can adapt to workers' activity patterns without compromising lighting comfort. These results indicate that the ESP32-based automatic lighting system with sound sensors is highly effective for reducing energy waste in companies. In addition to providing comfort for workers, this system helps companies reduce electricity costs and supports environmentally friendly energy efficiency programs.

B. *Product Defect Data Analysis*

Product defect analysis aims to identify the most common types of errors in the manufacturing process of ESP32-based automatic lighting systems, as well as to find their root causes. Defect data was collected from the inspection process on the production floor during a specific period and classified according to type.

The data on product defects recorded can be seen in the following table.

TABLE 3
PRODUCT DEFICIENCIES

No	TYPE OF DEFECT	NUMBER OF CASES	PERCENTAGE (%)
1	Imperfect solder connection	35	35%
2	Unresponsive sound sensor	28	28%
3	Firmware error	17	17%
4	Cracked casing	8	8%
5	Relay failure	7	7%
6	Untidy wiring	5	5%

Based on this data, a Pareto chart was created, as shown in the following figure, which shows the proportion of each type of defect.

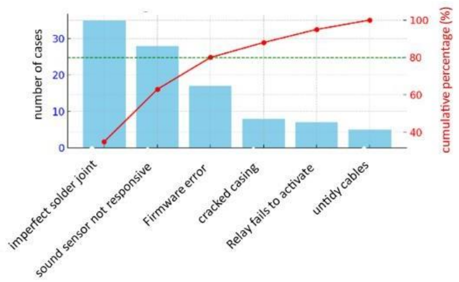

Figure. 7. Pareto Diagram of Product Defect Data

The diagram shows that the top three types of defects account for approximately 80% of the total problems, namely imperfect solder joints, unresponsive sound sensors, and firmware errors. Therefore, repair priorities are focused on these three issues in accordance with the Pareto 80/20 principle. A root cause analysis was then conducted using a Fishbone Diagram, as shown in the following figure. This diagram maps the causes of the issues into four main categories: Human, Machine, Method, and Material.

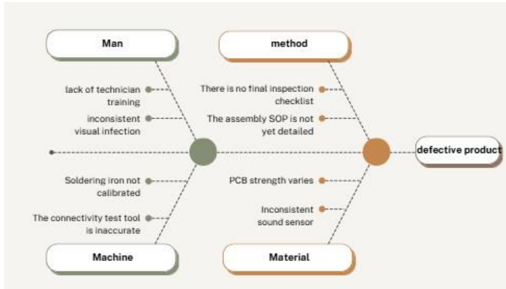

Figure. 8. Fish Bone Diagram Analysis of Product Defects

Based on the analysis results, field verification was conducted to confirm that the identified causes actually occurred in the production process. The results are presented in the following table.

TABLE 4
FIELD VERIFICATION OF ROOT CAUSES

No	CATEGORY	CAUSE	VERIFICATION STATUS	FIELD EVIDENCE
1	Man	Lack of technician training	■	Photo of technician training activities and attendance list
2	Man	Inconsistent visual inspection	■	Photo of incomplete visual inspection checklist form
3	Machine	Soldering equipment not calibrated	■	Photo of soldering tool with expired calibration label
4	Machine	Inaccurate connectivity testing tool	+	—
5	Method	Assembly SOP not detailed	■	Photo of old SOP document without final inspection stage
6	Method	No final inspection checklist	■	Photo of inspection area without available checklist form
7	Material	PCB quality variation	+	—
8	Material	Inconsistent sound sensor quality	■	Photo of sound sensor testing results using multimeter or oscilloscope

The verification results showed that six of the eight causes identified did occur in the field, while the other two were not found. This evidence reinforces the fact that most defects stem from technical factors that can be remedied through improved training, refinement of SOPs, and stricter quality control.

Discussion

This study successfully designed and implemented an automatic lighting system based on ESP32 and sound sensors aimed at energy efficiency by turning on the lights when there is sound and turning them off automatically after 10 minutes of silence, as well as enabling remote control via an IoT application, where testing showed energy savings of 37.5% and fast response times. although product defect analysis identified issues such as solder joint problems and firmware errors that require resolution.

4. CONCLUSION

Based on the research conducted, it can be concluded that the ESP32-based automatic lighting system with sound detection has been successfully implemented to improve energy efficiency. This system automatically turns on the lights when sound is detected and turns them off after 10 minutes of silence, resulting in energy savings of 37.5% in the company environment. Integration with the IoT platform enables remote control via smartphone, increasing user flexibility. However, product defect analysis revealed major issues with solder joints, unresponsive sensors, and firmware, which require improvements in technician training and production SOP to enhance system reliability.

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Attachment

Please enter the required attachments. If necessary, attachments can be split into Appendix A, Appendix B, and so on.

Curriculum Vitae

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