



PROTOTYPE DESIGN OF A BIRDSSTRIKE DETERRENT MONITORING SYSTEM BASED ON LCD DISPLAY AND ALARM NOTIFICATION AT AIRPORTS KUALANAMU INTERNATIONAL

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Abstrak

Perangkat pencegah tabrakan burung adalah alat pendukung keselamatan penerbangan yang digunakan untuk mengusir burung dari area operasional bandara guna meminimalkan risiko tabrakan burung. Keandalan peralatan ini bergantung pada kondisi operasionalnya; oleh karena itu, diperlukan sistem pemantauan untuk terus mengamati kinerjanya. Studi ini bertujuan untuk merancang dan mengimplementasikan prototipe sistem pemantauan berbasis ESP32 yang mampu memantau tegangan, arus, dan intensitas suara sebagai indikator kondisi operasional perangkat pencegah tabrakan burung. Sistem ini terdiri dari mikrokontroler ESP32, sensor arus INA219, sensor tegangan, sensor suara KY-037, LCD 20×4, dan bel. Tahapan penelitian meliputi desain perangkat keras, pengembangan perangkat lunak, implementasi sistem, pengujian akurasi sensor dengan membandingkan pembacaan sensor dengan instrumen pengukuran standar, dan pengujian respons sistem berdasarkan nilai ambang batas yang telah ditentukan. Hasil pengujian menunjukkan bahwa sistem mampu mengukur tegangan, arus, dan intensitas suara secara real-time, menampilkan informasi pemantauan pada LCD, dan mengaktifkan bel setiap kali parameter yang dipantau berada di bawah ambang batas yang telah ditentukan. Oleh karena itu, prototipe yang dikembangkan berhasil menjalankan fungsi pemantauan kondisi operasional alat pencegah tabrakan burung dan dapat berfungsi sebagai solusi alternatif untuk mendukung pemeliharaan fasilitas pendukung keselamatan penerbangan.

Kata Kunci: Pencegahan Tabrakan Burung, ESP32, Sensor INA219, Sensor Tegangan, Sensor Suara KY-037, Pemantauan

Abstract

A birdstrike deterrent is an aviation safety support device used to repel birds from airport operational areas in order to minimize the risk of bird strikes. The reliability of this equipment depends on its operational conditions; therefore, a monitoring system is required to continuously observe its performance. This study aims to design and implement an ESP32-based monitoring system prototype capable of monitoring voltage, current, and sound intensity as indicators of the operational condition of the birdstrike deterrent. The system consists of an ESP32 microcontroller, an INA219 current sensor, a voltage sensor, a KY-037 sound sensor, a 20×4 LCD, and a buzzer. The research stages included hardware design, software development, system implementation, sensor accuracy testing by comparing sensor readings with standard measuring instruments, and system response testing based on predetermined threshold values. The test results indicate that the system is capable of measuring voltage, current, and sound intensity in real time, displaying monitoring

information on the LCD, and activating the buzzer whenever any monitored parameter falls below the predefined threshold. Therefore, the developed prototype successfully performs the monitoring function of the birdstrike deterrent's operational condition and can serve as an alternative solution to support the maintenance of safety aviation support facilities.

Keyword: *Birdstrike Deterrent, ESP32, INA219 Sensor, Voltage Sensor, KY-037 Sound Sensor, Monitoring*

INTRODUCTION

Indonesia is the world's largest archipelagic country, comprised of thousands of islands and boasting exceptionally high biodiversity (Hammam & Feriansah, 2020). Indonesia's natural riches encompass a diverse range of flora and fauna, including widespread bird populations (Theodorus Nofri Ratu, Y Rindengan, 2022). Its geographical location and tropical climate make Indonesia a natural habitat for numerous bird species.

However, according to ICAO (International Civil Aviation Organization) Annex 14 on Aerodromes, the presence of wildlife, particularly birds, around airports is a risk factor that can affect the safety of flight operations and must be controlled through a Wildlife Hazard Management program to minimize the potential for birdstrikes. On the other hand, the development of the air transportation sector in Indonesia has experienced significant growth from year to year. Airports, as vital infrastructure in the air transportation system, play a crucial role in ensuring flight safety and security (Lutfi Prihatin, 2022).

Interactions between aircraft and birds can lead to birdstrikes, which are collisions between aircraft and birds that can potentially damage the aircraft and endanger flight safety. In Indonesia, birdstrikes remain a serious aviation safety concern. Research shows that birdstrikes commonly occur in critical areas such as runways and aprons, particularly during takeoff and landing (Saputri et al., 2025).

The presence of birdstrike deterrent equipment is crucial because it serves as the first line of defense in preventing interactions between birds and aircraft. Without such equipment, the potential for birdstrikes increases, which can result in aircraft engine damage, flight schedule disruptions, and even the risk of accidents (Raihan & Firmawati, 2022).

Therefore, various airports use birdstrike deterrent devices as a means of mitigating this risk. However, the effectiveness of this equipment is highly dependent on operational conditions and the monitoring system used. One common obstacle is the lack of a monitoring system capable of providing rapid information on the equipment's condition, resulting in the inability to detect damage or disruptions immediately.

Based on observations during On-the-Job Training (OJT) at Kualanamu International Airport, it was discovered that technicians experienced difficulties in monitoring the condition of the birdstrike deterrent equipment scattered throughout the airport. The remote location of the equipment and the manual monitoring system prevented routine checks from being carried out at all times (Arief et al., 2024). Maintenance activities are generally carried out within a specific timeframe, so if a disruption occurs outside of this schedule, the condition of the equipment cannot be immediately identified. This has the potential to cause the equipment to not function optimally in repelling birds in the airport's operational area.

Furthermore, the lack of a system capable of directly displaying critical parameters such as voltage, current, and the operational status of equipment presents a challenge during maintenance. Monitoring electrical parameters such as voltage and current can be used as early indicators to determine a device's operating condition more quickly and accurately (Rahman et al., 2020).

Based on these problems, a solution is needed in the form of a simple, effective, and easy-to-implement monitoring system. Therefore, this study designed a prototype of a birdstrike deterrent monitoring system based on an LCD display and alarm notification, capable of

providing real-time information on the equipment's condition and early warning to technicians in the event of a disruption (Avista et al., 2024).

This prototype is a representation of the real conditions in the field of a monitoring system that can be an alternative solution and be implemented in an airport environment, so that it can increase the effectiveness of birdstrike deterrent equipment maintenance and support flight operational safety (Lukman Prihasworo, Dhanis Woro Fittrin, Unan Yusmaniar Oktiawati, Hidayat Nur Isnianto, 2020).

RESEARCH METHOD

A research method is a systematic method or step used by researchers to obtain data, process information, and draw conclusions that align with the research objectives. Selecting the right research method is crucial because it will determine the research process and the quality of the results (Handari, 2012).

This research employed a Research and Development (R&D) method, focusing not only on analysis but also on the design and development process of a product. The product in question is an ESP32-based Birdstrike monitoring system prototype capable of displaying device conditions in real time via LCD and providing alarm notifications (Rumayani et al., 2020).

The R&D method was chosen because it aligns with the characteristics of research, which involves not only analysis but also system design, construction, and testing. This approach allows researchers to develop a system gradually until optimal results are achieved and can be used as a solution to existing problems in the field. This aligns with research that states that the R&D method is effective in developing technology-based systems because it combines the design, implementation, and evaluation processes in a single, systematic flow (Pratama, 2022). A well-designed research flow also facilitates time management and the achievement of research targets

The first stage in designing this tool is to compile a block diagram as an initial representation of the system to be created. The block diagram functions to provide a general overview of the overall circuit workflow, so that the designed system can operate in accordance with the research objectives.

The testing phase was conducted to determine whether the system was working as expected. Accuracy testing was conducted by comparing sensor readings to standard measuring instruments. System response testing aimed to determine the system's speed in detecting abnormal conditions. Data analysis techniques in this study were carried out quantitatively and descriptively to evaluate the performance of the designed monitoring system. The analysis was carried out by examining the performance of each main component, including the current sensor, voltage sensor, noise sensor (dB), ESP32 as a data processor, and output devices in the form of an LCD and buzzer. This evaluation aimed to ensure that all system components function according to their designed functions and are able to provide accurate and responsive information on device conditions.

Sensor accuracy analysis is performed to determine the level of accuracy of sensor readings compared to standard measuring instruments. Accuracy is calculated based on the difference between the sensor value and the measuring instrument value, expressed as a percentage as follows: (Krisnawijaya & Adrama, 2019).

Research and testing of tools (mockups) for the Birdstrike monitoring system prototype design at the Medan Aviation Polytechnic. Implementation is scheduled to begin in March 2026.

RESULTS AND DISCUSSION

The research results are the implementation stage of the *monitoring system prototype design*. The *birdstrike deterrent system* was designed in Chapter III. This stage aims to translate the system design into a *prototype* capable of monitoring the operational condition of the *birdstrike deterrent device* in real time (Suriana et al., 2022).

The *prototype* implementation was carried out in stages starting from the arrangement of the power supply circuit, installation of ESP32, installation of the INA219 sensor as a current sensor, installation of the voltage sensor, installation of the KY-037 sound sensor, installation of the LCD, *buzzer* , and arrangement of the entire circuit into one integrated system. After all the hardware was assembled, software development was carried out using the Arduino IDE before the testing process was carried out on the entire system.

The results of the implementation are explained systematically in the following sub-chapters, starting from the hardware creation process, software development, synchronization between hardware and software, to a discussion of the test results based on the testing techniques explained in Chapter III.

Hardware Manufacturing

This research requires several pieces of hardware connected to each other. The hardware design is divided into several sections.

Power Supply Circuit

In this study, a *Power Supply Unit* (PSU) with an output of 12 Volts DC and a maximum current of 3 Amperes was used as the system's main voltage source. Power flow begins with a 220 VAC PLN electricity source, which is converted to DC voltage by the *Power Supply Unit* . The PSU's output voltage is then passed to the LM2596 module to be reduced to the system's operating voltage. The LM2596 output voltage is then distributed to the ESP32 (Yuliawan et al., 2020).

INA219 sensor, voltage sensor, KY-037 sound sensor, 20×4 LCD, and *buzzer* . All components use the same *ground path* (*common ground*) so that data communication and power distribution can take place properly.

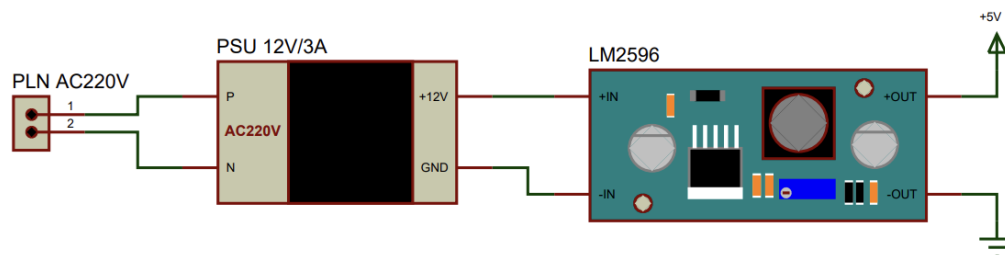


Figure 1. *Power Supply and LM2596 Connection*

ESP32 circuit

Begin by installing the module on the assembly board (*baseboard*) to simplify the wiring process for all components. Once the ESP32 module is installed, the next step is to connect the power supply pins (*VIN* and *GND*) to the outputs of the LM2596 module (Zhou et al., 2020).

Next, the communication path between the ESP32 and all sensors and output devices is installed according to the pin configuration determined during the design stage. The KY-037 sound sensor is connected to one of the ESP32's analog pins so that the analog signal generated by the sensor can be read and processed into information about the speaker's sound intensity. Next, a *buzzer* is installed on one of the ESP32's digital pins, which functions as an output to generate an alarm when the system detects an abnormal condition (Yassin & Juleet, 2018).

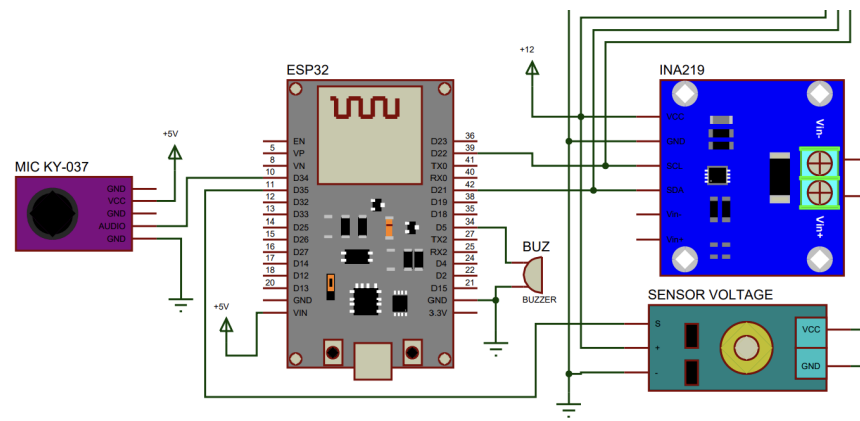


Figure 2. ESP 32 installation

After all connections are complete, each cable connection is rechecked to ensure there are no pin placement errors or short circuits. This inspection stage is crucial because errors in the communication path can prevent the microcontroller from detecting the sensor or cause the system to fail (Surya, 2020).

Series Liquid Crystal Display (LCD) 20x4

The LCD installation stage is carried out after all sensors have been successfully integrated with the ESP32. This ensures that sensor readings can be displayed immediately after being received and processed by the microcontroller. The LCD used in this study is a 20x4 LCD equipped with an I²C (Inter-Integrated Circuit) module.

The installation process begins by connecting the VCC pin on the LCD module to the +5 Volt output of the LM2596 module. Next, the Ground (GND) pin is connected to the Ground (GND) pin of the ESP32 as a voltage reference. After the power supply line is installed, the LCD SDA (Serial Data) pin is connected to the ESP32 GPIO21 pin, while the SCL (Serial Clock) pin is connected to the ESP32 GPIO22 pin. Both lines are used as I²C communication media between the LCD and the microcontroller (Saputri et al., 2025).

Buzzer Circuit

buzzer installation stage is carried out after all sensors and the LCD have been successfully integrated with the ESP32. This final installation stage allows the buzzer to be directly tested based on the readings of all sensors that are functioning properly.

The installation process begins by connecting the buzzer's positive terminal (VCC) to one of the ESP32's digital pins, GPIO5, which has been designated as an output pin in the program. The buzzer's negative terminal (GND) is then connected to the ESP32's ground pin so that the circuit has the same voltage reference path as the other components (Saputra & Wijaya, 2023).

Software Development

Software is part of the system that controls the entire prototype's work process, from reading sensor data and processing it to sending information to the output device. In this study, the software was developed using the Arduino IDE with the C/C++ programming language adapted to the ESP32 microcontroller's specifications.

ESP32 Program

threshold values were defined as decision-making parameters in the monitoring system. These threshold values included minimum voltage, current, sound intensity, and alarm activation duration.

```
// Setting
#define MIN_VOLT 3.0
#define MIN_Arus 0.10
#define MIN_DB 60
#define ALARM_TIME 30
#define FAKTOR_I 1.00
#define FAKTOR_V 1.00
```

This program code indicates that the system uses a minimum voltage limit of 3 volts, a minimum current limit of 0.10 amperes, and a minimum sound intensity limit of 60 dB. If any of these parameters falls below these limits, the system will activate *the buzzer* for 30 program cycles as an indicator of interference with the *birdstrike deterrent device* (Raje, 2022).

Next, the library is called which is used to connect the ESP32 with all the hardware.

This program code shows that the ESP32 uses the Wire.h library for I²C communication, INA219 for reading current and voltage, LiquidCrystal_I2C for controlling the LCD, and RunningMedian for stabilizing the sound sensor readings. It also declares the pins used by each device (Ramadhan, 2023).

The next stage is the initialization process for all devices which is carried out in the setup() function.

```
void setup()
{
    Serial.begin(9600);
    analogSetPinAttenuation(VOLTAGE_PIN, ADC_11db);
    pinMode(CHECK_IN, INPUT_PULLUP);
    pinMode(BUZZ_PIN, OUTPUT);
    analogReadResolution(12);
    analogSetPinAttenuation(MIC_PIN, ADC_11db);
}
```

In this program code, the serial communication initialization process, input and output pin configuration, LCD activation, I²C communication, and INA219 sensor configuration are carried out so that all devices are ready to use before entering the *monitoring process*.

After the initialization process is complete, the ESP32 runs the loop() function which functions to run the *monitoring system* continuously.

This program code shows that the system uses a simple *state machine method*. The value process = 0 is used to run the *monitoring process*, while process = 10 is used when the system detects an abnormal condition and enters warning mode.

In the SystemUtama() function, the ESP32 reads all sensor data and then displays the results on the LCD.

This program code shows the ESP32 reading voltage data using the readVoltage() function, reading current using the INA219 sensor, and reading sound intensity using the cekSound() function. All readings are then displayed on the LCD to *monitor* the device's condition.

After all sensor data is collected, the system performs a decision-making process by comparing the readings to a predetermined minimum limit. This program code indicates that the system will issue a warning if the voltage, current, or sound intensity falls below the specified minimum limit. This logic forms the basis for decision-making in the *monitoring system*.

If the system detects an abnormal condition, the ESP32 will execute the Warning() function.

```
void Warning() {
    if (cntAlarm > 0) {
        cntAlarm--;
        Serial.println("cntAlarm" + String(cntAlarm));
        if (cntAlarm > 0) {
            digitalWrite(BUZZ_PIN, !digitalRead(BUZZ_PIN));
            lcd.setCursor(0, 0);
            lcd.print("    WARNING !!!!!    ");
        }
    }
}
```

This program code indicates that *the buzzer* is activated by flashing (*toggle*) as an alarm, while the LCD displays warning information along with the parameters that are experiencing interference so that the user can immediately find out the cause of the alarm.

LCD Display Implementation

The LCD display is implemented after all sensors have been successfully integrated with the ESP32. All data obtained from the INA219 sensor, voltage sensor, and sound sensor is processed by the ESP32, then sent to the LCD using I²C communication. This method allows for periodic data updates according to the reading interval specified in the program.

Under normal conditions, the LCD will display the system identity on the first line, while the next line displays the reading results of each sensor. The voltage value is displayed in Volts (V), the current value in Amperes (A), while the sound intensity is displayed in decibels (dB). In addition, the lower right part of the LCD displays the device's operating status, which is ON if the *birdstrike deterrent device* is working and OFF if the device is not operating. This program code indicates that the system will display the OFF status if the device is not operating and display the ON status when the *birdstrike deterrent device* is active.

If the system detects a parameter outside normal limits, the LCD display will change to a warning display. This display aims to provide the user with information about the affected parameter so that the damage can be identified more quickly.

This program code shows that when the system detects an abnormal condition, the LCD will display the word *WARNING* on the first line, while the next three lines display the parameters that are experiencing problems, namely voltage, current, and sound intensity.

The LCD display implementation developed in this research provides clear and easily understood system condition information to users. This information helps operators monitor the condition of the *Birdstrike deterrent device* directly without the need for additional software.



Figure 3. LCD Display Under Normal Conditions

Discussion of Research Results

The device that has been programmed and assembled is then tested system to determine whether all components can work well according to plan.

Test Results

After the hardware and software design and implementation process is completed, the next stage is to carry out testing on the *monitoring system prototype . Birdstrike deterrent*. The test aims to determine the system's success rate in *monitoring* voltage, current, and sound intensity parameters, as well as its ability to provide warnings when conditions occur that do not comply with predetermined limits.

Testing in this study was conducted using the methods described in Chapter III, namely sensor accuracy testing and system response testing. Accuracy testing was conducted by comparing the readings of each sensor against a standard measuring instrument, while system response testing was conducted to determine the system's ability to issue an alarm when an abnormal condition occurs.

Sensor Accuracy Testing

Table 3. INA219 current sensor accuracy test results

No	Multimeter Current (A)	INA219 (A) Sensor	Differen ce	Accuracy (%)
1	0.20	0.22	0.02	90
2	0.21	0.22	0.01	95.30
3	0.20	0.22	0.02	90
4	0.22	0.22	0	100
5	0.21	0.21	0	100
6	0.20	0.20	0	100
7	0.20	0.22	0.02	90
8	0.21	0.21	0	100
9	0.21	0.22	0.01	95.30
10	0.22	0.22	0	100

Based on the test results in Table 4.8, the INA219 sensor is capable of reading current values with a good level of accuracy. The difference in readings is still within tolerance limits, making the sensor suitable for use as a current *monitoring device in the system*.

Based on the test results, it was found that the voltage sensor was able to read voltage values close to those measured using a voltmeter. The small difference in readings indicates that the sensor has a good level of accuracy, making it suitable for use as a *monitoring parameter in the prototype*.

Test results showed that the KY-037 sensor was able to detect changes in sound intensity effectively. Although there was a slight difference compared to a comparable measuring instrument, the error value was still within acceptable limits, making the sensor suitable for use as a sound intensity *monitoring device* (Rahman & Prasetyo, 2020).

System Response Testing

The next step after verifying sensor accuracy is to test the system's response to changing conditions. This testing involves running a simulation to reduce the voltage, current, and sound intensity parameters below the minimum limits set by the ESP32 microcontroller.

Table 4. Testing the buzzer response and LCD display

No	Condition Testing	LCD	Buzzer	Results
1	All parameters are normal	✓	✓	
2	Voltage < 3 Volts	✓	✓	

3	Current < 0.10 A	✓	✓
4	Sound < 60 dB	✓	✓
5	More than one parameter is abnormal	✓	✓



Based on the test results, the system is able to provide a response according to the logic programmed into the ESP32 (Gullipalli & Golla, 2020). When all parameters are in normal condition, the LCD displays the *monitoring results information* without activating the *buzzer* (Hidayat et al., 2021). Conversely, if one of the parameters is below the specified threshold value, the LCD displays a *WARNING message* along with information about the parameter experiencing a disturbance, while the *buzzer* is active as an indicator of an abnormal condition. This shows that the *monitoring system* has worked according to the expected design and is able to carry out the warning function automatically (Organization, 2018).

Advantages and Disadvantages of Tools

After the design, implementation and testing process for the *monitoring system prototype* was carried out *birdstrike deterrent*, several advantages and disadvantages were obtained which can be used as evaluation material for system development in further research.

Monitoring system prototype The developed *birdstrike deterrent* has several advantages as follows: (1) Able to do real-time *monitoring*. (2) Integrate multiple sensors in one system (Pratama, 2022). (3) Provides automatic warnings when a disturbance occurs. (4) Has an easy-to-understand information display. (5) Using components that are relatively economical and easy to obtain. (6) Easy to develop in further research.

Apart from having several advantages, the *prototype* that was developed also still has several limitations, including the following (Pratama & Sari, 2023): (1) *Monitoring* is still local. (2) Sound sensors are still affected by environmental conditions. (3) Storage media is not yet available. (4) The threshold value is still determined manually. (5) Testing is still being done on a *prototype scale*. Not equipped with an automatic disturbance type identification system.

CONCLUSION

Based on the results of the design, implementation, testing, and analysis of the ESP32-based *birdstrike deterrent monitoring system prototype*, the following conclusions can be drawn: (1) The *prototype of the birdstrike deterrent monitoring system* was successfully designed and

implemented using ESP32 as a control center integrated with the INA219 sensor, voltage sensor, KY-037 sound sensor, 20x4 LCD, and *buzzer*. All components can work in an integrated manner according to the system design that has been made so that it is able to carry out the *monitoring function of the birdstrike deterrent* device condition. (2) Based on the results of sensor accuracy testing, the INA219 sensor is able to measure the value of electric current, the voltage sensor is able to measure the voltage value, and the KY-037 sound sensor is able to detect the intensity of sound produced by the *birdstrike deterrent speaker*. The reading results of each sensor have values close to the comparative measuring instrument so that they can be used as *monitoring parameters* in the system. (3) *The prototype* is capable of *monitoring the condition of the Birdstrike deterrent device in real time*. Sensor readings are processed by the ESP32 and displayed on the LCD, allowing users to directly monitor the voltage, current, sound intensity, and operational status of the device. (4) The system successfully provides an automatic response when one of the *monitoring parameters* is below the threshold value *specified* in the program. In this condition, the LCD displays *WARNING information*, while the *buzzer* is active as an alarm so that users can immediately find out if there is an indication of interference with the *birdstrike deterrent device*. Based on the results of the implementation and testing that have been carried out, *the prototype* developed has met the research objectives, namely producing an ESP32-based *monitoring system* that is able to monitor the condition of the *birdstrike deterrent device* through voltage, current, and sound intensity parameters and provide early warnings if an abnormal condition occurs.

Suggestion

Based on the results of the research that has been conducted, there are several suggestions that can be used as development material for further research, namely as follows. (1) *The prototype* can be developed by adding a remote monitoring feature using a Wi-Fi network or the Internet of Things (IoT), so that the condition of the *birdstrike deterrent device* can be monitored without having to be at the device location. (2) The system can be developed by adding data storage media (*data logging*), such as an SD card (*MicroSD Card*) or database, so that all *monitoring results* can be recorded and used as evaluation material or historical analysis. (3) The sound sensor used can be replaced with a sensor that has a higher level of accuracy or combined with a digital signal processing method (*Digital Signal Processing/DSP*) to reduce the influence of noise from the surrounding environment. (4) Further research can develop the system by adding a condition analysis feature (*diagnostic system*) that is able to identify the type of disturbance automatically based on the pattern of changes in voltage, current, and sound intensity parameters, so that the maintenance process can be carried out more quickly and precisely.

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