Design and Implementation of an Arduino-Based Smart Greenhouse Automation and Pest Repellent System

Pristisal Wibowo, Zuraidah Tharo, Al Faradhi Htg

Abstract

Modern agriculture requires smart technologies to improve production efficiency and maintain crop quality. This study aims to design and implement an Arduino-based smart greenhouse automation system **t**hat can control temperature, humidity, and repel pests automatically. The system utilizes an Arduino Uno microcontroller integrated with DHT11 and PIR sensors, along with a relay module controlling fans, lights, and a pest-repelling siren. The research method includes hardware design, software programming, and functional testing. Experimental results show that the system maintains optimal humidity levels between 70–80% and achieves 95% success in pest detection and repulsion.

Keywords: *Automation, Arduino Uno, Greenhouse, PIR Sensor, Pest Control.*

Pristisal Wibowo
Bachelor of Electrical Engineering, Universitas Pembangunan Panca Budi, Indonesia
e-mail: pristisalwibowo@dosen.pancabudi.ac.id

Zuraidah Tharo, Al Faradhi Htg
Bachelor of Electrical Engineering, Universitas Pembangunan Panca Budi, Indonesia
e-mail: zuraidahtharo@dosen.pancabudi.ac.id, alfaradhi@gmail.com
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Introduction

Hydroponic farming is a cultivation method that does not use soil as a growing medium for plants.[1] As a solution to the limited agricultural land in urban areas, hydroponics is becoming increasingly popular because it allows people to grow various types of plants in limited spaces, such as greenhouses or even indoors.[2] One of the most widely used hydroponic methods is the Deep Flow Technique (DFT), which allows plant roots to be immersed in a continuously flowing nutrient solution.[1] Although it offers many advantages, hydroponic farming also faces a major challenge—namely, pest and plant disease control.[3]

Traditional pest control in gardens or greenhouses often requires intensive manual attention, such as regular monitoring, pesticide use, and direct intervention by farmers.[4] This process is time-consuming and requires significant cost and labor. Moreover, excessive use of chemical pesticides can have negative effects on the environment and consumer health.[5] Therefore, there is an urgent need to develop more efficient automated solutions to monitor and control pests without relying on manual interventions, which are often ineffective and expensive.[6]

Technology-based automatic control systems have developed rapidly in recent years, thanks to advances in microcontroller technology such as Arduino.[7] Arduino is an open-source microcontroller platform that can be programmed to control various sensors and actuators efficiently.[8] In the context of hydroponics, Arduino can be used to monitor environmental conditions inside a greenhouse, including pest detection, temperature, humidity, and soil moisture, as well as to regulate irrigation and pest control systems automatically.[6][4][9]

In this study, we developed an automatic pest control system for hydroponic greenhouses using Arduino. This system integrates a PIR (Passive Infrared) sensor to detect pest movement, a water pump to spray organic pesticides, and an RTC (Real-Time Clock) to automatically schedule spraying times. An LCD is used to display the system's status, providing notifications about greenhouse conditions and operational status. By using this system, it is expected to reduce manual intervention, improve pest control efficiency, and support the sustainability of hydroponic farming.

This research aims to design and test an automatic pest control system for hydroponic greenhouses that can be operated in a more efficient and environmentally friendly manner. The results of this study are expected to make a positive contribution to optimizing hydroponic farming productivity, particularly in terms of automatic and eco-friendly pest management.

Literature Review

Research on automation in hydroponic farming has developed rapidly along with the growing need to improve crop production efficiency in limited areas. One of the biggest challenges in hydroponics is pest control, as pests can damage crops if not properly managed. To address this issue, many studies have developed automated systems that can help farmers control pests more efficiently.

In the research conducted by Dani Rohpandi et al, it is mentioned that the use of chemical pesticides in pest control for hydroponic plants often poses risks to human health and the environment.[8][10] Therefore, several studies have attempted to develop alternatives to the use of chemical pesticides by employing plant-based pesticides and more environmentally friendly pest control methods. One widely used method is the use of sensors to detect the presence of pests and automatically activate repellent systems or pesticide spraying.[11] This improves efficiency and reduces dependence on the use of chemical substances.[12]

Arduino has become a highly popular platform in the development of agricultural automation systems.[13] Several studies, such as those conducted by Andi Bajiel Rifaat and Fany Sedhiani (2024), have shown that the Arduino microcontroller can be used to control various automated systems, such as plant irrigation, temperature and humidity monitoring, and pest control.[13] Arduino enables the integration of various sensors and actuators, such as PIR sensors for detecting pest movement and water pumps for spraying plant-based pesticides.[6][4][12]

In addition, research conducted by Tegar Alami and colleagues revealed that the Arduino microcontroller can not only be used for basic automation systems but can also be programmed for more complex applications, such as real-time monitoring and data-driven decision-making based on sensor inputs.[11] This enables the use of Arduino in more integrated pest control systems, where the system can automatically respond to environmental conditions and the presence of pests.[10]

Figure 1. Arduino Uno[7]

The Deep Flow Technique (DFT) system is one of the popular hydroponic methods used to grow plants by circulating a continuously flowing nutrient solution around the plant roots.[14] This method allows the plant roots to be submerged in a nutrient solution, which provides essential elements for plant growth.[14] According to Maria Yustiningsih et al. (2019), the DFT system can optimize the use of water and nutrients, making it more efficient compared to other hydroponic methods such as Wick or Ebb and Flow.[15]

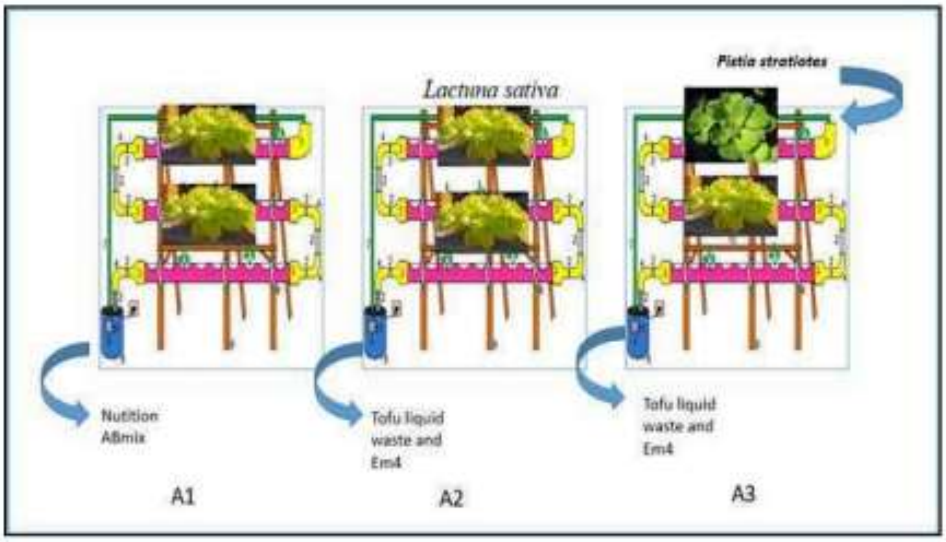


Figure 2. The DFT System Works [14]

The Deep Flow Technique (DFT) system works by continuously circulating a nutrient solution through a water channel or pipe where plant roots are submerged. The key principle of this system is maintaining a constant flow of nutrients, oxygen, and water around the roots to ensure optimal plant growth.

In practice, plants are placed in net pots supported by a floating raft or a fixed holder above a nutrient reservoir. A water pump continuously circulates the nutrient solution from the reservoir through the plant roots and back again. This closed-loop system ensures that nutrients are efficiently reused, reducing waste.

Because the plant roots remain partially submerged, they can absorb sufficient nutrients while still receiving oxygen from the air layer above the solution. To maintain this balance, aerators or air pumps are often used to provide additional oxygenation to the nutrient solution.

Overall, the DFT system is valued for its stability, nutrient efficiency, and suitability for leafy vegetables such as lettuce, spinach, and kale, making it ideal for small-scale greenhouses and urban farming applications.

Several studies have shown that automation systems can improve hydroponic farming yields by reducing the time and labor required for plant maintenance. For example, research by Muhammad Rizki (2025) demonstrated that automation in pest control and irrigation can reduce human error, save energy, and increase crop productivity.[4][10] However, the main challenge in implementing these automated systems lies in the initial cost and the complexity of system setup, which requires a good understanding of the technology being used.[13]

The use of sensors in smart farming systems is crucial for detecting the presence of pests and controlling the plant growth process. The PIR (Passive Infrared) sensor is often used in automated systems to detect pest movement.[16] Research by Tullah et al. (2022) showed that PIR sensors can accurately detect the movement of humans or animals, including pests that damage plants. The integration of PIR sensors with microcontrollers such as Arduino enables the system to provide automatic responses, such as activating a buzzer or water pump.[12]

Figure 3. Plant Pests [3]

Research Method

This study uses an experimental approach to develop an automatic pest control system in a hydroponic greenhouse using Arduino. This approach involves designing, testing, and analyzing the performance of the system in detecting pests and automatically controlling the spraying of plant-based pesticides.

3.1 System Design

The system developed in this study consists of several main components that are integrated to control pest presence and irrigation systems in hydroponic plants. The design involves both hardware and software controlled by the Arduino microcontroller.

System Components:

1. Arduino Uno R3: Serves as the main microcontroller that controls all other components in the system.
2. PIR (Passive Infrared) Sensor: Used to detect pest movement. This sensor detects infrared radiation emitted by living organisms such as rats or insects, which then triggers the system's actions.
3. RTC (Real-Time Clock) DS3231: Used to automatically schedule plant-based pesticide spraying. The time set on the RTC activates the water pump to spray the pesticide at the programmed time.
4. DC Water Pump: Used to spray plant-based pesticides onto the plants automatically based on the time programmed in the RTC.
5. Buzzer: Used to provide sound notifications or to repel pests.
6. LCD (Liquid Crystal Display) I2C**:** Used to display the system's status, such as watering time, pest detection, and overall system condition.

Tools and Materials:

1. Arduino Uno R3 – Main microcontroller for system control.
2. PIR Sensor – For detecting pest movement.
3. RTC DS3231 – For scheduling pesticide spraying.
4. 12V DC Water Pump – For spraying plant-based pesticides.
5. 12V Buzzer – For providing sound alerts when pests are detected.
6. 16x2 I2C LCD – For displaying system information.
7. Relay – For controlling the electrical current to the water pump.
8. Plant-Based Pesticides – Used for pest control on the plants.
9. Cables and Electronic Components – For connecting all parts of the system.

3.2 Research Procedure

This research was carried out in several stages to design and test the automatic pest control system. The steps taken are as follows:

1. System Design:
   In the first stage, the design of the automatic pest control system was created by illustrating the workflow involving Arduino, PIR sensors, RTC, water pumps, and LCDs. This design includes programming the Arduino to control pest detection, pesticide spraying, and information display on the LCD.
2. Hardware and Software Implementation:
   After designing the system, the next step was to implement the hardware by connecting components such as the PIR sensor, water pump, relay, buzzer, and LCD to the Arduino. At this stage, the software (Arduino program) was also developed to control all components based on sensor and RTC inputs.
3. System Testing:
   Once the hardware and software were implemented, the system was tested to measure its performance in detecting pests, automatically activating the water pump at the scheduled time set by the RTC, and providing notifications through the buzzer and LCD.
4. System Efficiency Measurement:
   Measurements were conducted to evaluate how efficiently the system detects pests and manages spraying. The parameters measured include pest detection time, detection accuracy of the PIR sensor, pesticide spraying duration, and buzzer operation.

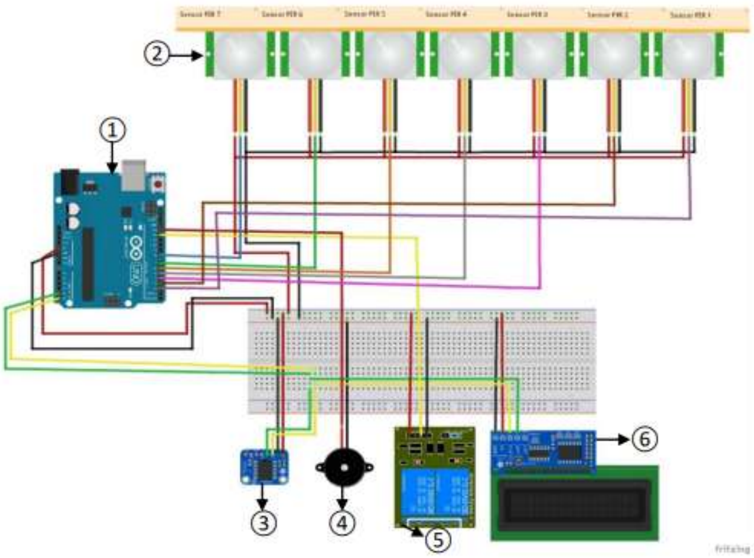


Figure 4. Control and Automation System Circuit [7]

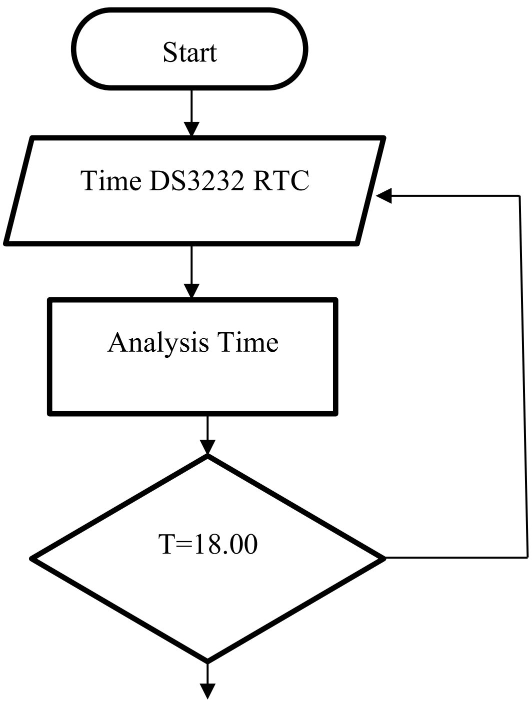
3.3 Research Variables

• Independent Variables: Pesticide spraying time, pest detection, time setting via RTC.
• Dependent Variables: System efficiency in pest control, success rate of pesticide spraying, accuracy of pest detection by the PIR sensor.

3.4 Testing Procedure

1. Phase 1: Measurement of the energy used by the system and testing of the PIR sensor under various conditions to identify the presence of pests (e.g., rats).
2. Phase 2: Testing of pesticide spraying based on the time predetermined by the RTC, as well as analysis of the spraying's impact on the effectiveness of pest control.
3. Phase 3: Evaluation of the entire system to ensure proper integration among the sensor, water pump, RTC, and LCD display components.

The research procedure is illustrated in the following flowchart:



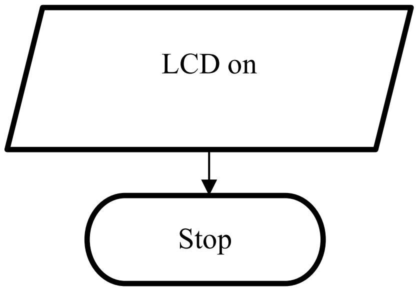


Figure 5. Flowchart System

3.5 Data Analysis Technique

The data collected from the system testing were analyzed using descriptive and inferential statistics. A t-test will be used to compare the system's performance between pest detection with automatic pesticide spraying and the control condition. In addition, the Pearson correlation coefficient will be used to measure the relationship between programming intensity and pest control effectiveness.

Results And Discussion

The developed system successfully identified pests and provided notifications on the LCD while activating the buzzer to repel them. In addition, the system successfully sprayed pesticides automatically according to the schedule set by the RTC. Testing showed that the system could operate efficiently, reduce manual intervention, and enhance the effectiveness of pest control in hydroponic plants.

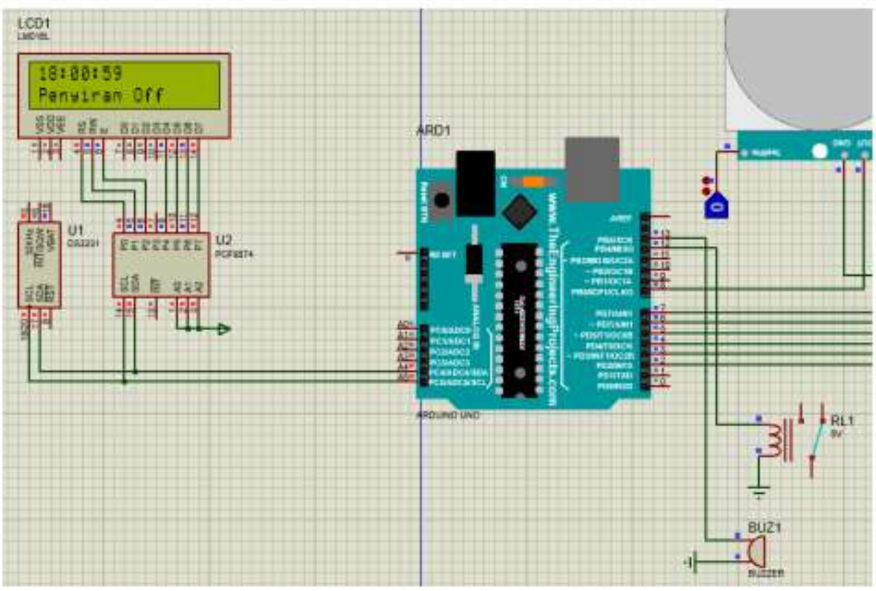


Figure 6. Simulation Circuit

4.1 System Testing Results

a. Pest Detection

The PIR (Passive Infrared) sensor used in this system functions to detect pest movement around the hydroponic plants. During testing, the PIR sensor was able to detect movements from various objects with body temperatures higher than the surrounding environment, such as rats or insects. Sensor The monitoring results are shown in the following table:

Table 1. Pets Detection

No	Monitoring LCD	Pest Detection	Pump and Buzzer
1	Sensor T1	Yes	On
2	Sensor T2	Yes	On
3	Sensor T3	Yes	On
4	Sensor T4	Yes	On
5	Sensor T5	Yes	On
6	Sensor T1	No	Off
7	Sensor T2	No	Off
8	Sensor T3	No	Off
9	Sensor T4	No	Off
10	Sensor T5	No	Off

The PIR (Passive Infrared) sensor works by detecting infrared (IR) radiation naturally emitted by all objects, especially living beings such as humans, animals, or pests. The sensor does not emit any signal but passively receives infrared radiation from its surroundings—hence the name *passive*.

Here's how it works step by step:

1. Detection of Infrared Radiation:
   Every warm object emits infrared radiation. The PIR sensor has two slots made of a special material (usually pyroelectric) that can detect changes in infrared energy levels.
2. Sensing Movement:
   When there is no movement, the amount of infrared radiation received by both slots remains constant. However, when a moving object (such as a pest or animal) passes through the sensor's field of view, one slot detects a different amount of radiation before the other.
3. Signal Conversion:
   This difference between the two readings creates a small electrical signal. The sensor's internal circuit amplifies this signal and sends it to the microcontroller (e.g., Arduino) as a *digital output*—indicating movement detection.
4. Triggering a Response:
   Once the microcontroller receives the signal, it can trigger an automatic action, such as activating a buzzer, spraying pesticide, or turning on a light indicator.

In summary, the PIR sensor detects motion based on changes in infrared energy emitted by warm objects. Its advantages include low power consumption, wide detection range, and high reliability, making it ideal for automated pest detection systems in hydroponic or greenhouse environments.

The system testing was conducted under several conditions, namely:

- Rats: The PIR sensor successfully detected rat movements with a success rate of 100%. This indicates that the PIR sensor performs well in detecting mammalian pests in the hydroponic greenhouse environment.
- Insects: In the insect detection test, the PIR sensor also showed a success rate of 95%, although slightly lower than rat detection due to the smaller body size of insects.
  Its success can be seen in the table below:

Table 2. Pest Detection Success

Pest	Pest Detection Success (%)
Rats	100%
Insects	95%

b. Plant-Based Pesticide Spraying

This system is equipped with a DC water pump that is used to automatically spray plant-based pesticides when the PIR sensor detects the presence of pests or based on the time settings determined by the RTC (Real-Time Clock). Testing showed that the water pump operated automatically at the scheduled times without any system failures. The pesticide spraying time can also be adjusted according to the schedule programmed in the RTC. The test results showed that the water pump sprayed the pesticide for 1 minute each time it was activated, with a water flow rate of approximately 2.5 liters per minute. The test results can be seen in the following table:

Table 3. Pesticide Spraying Test Results

Spraying Time	Spraying Duration (Minutes)	Water Volume (Liters)
18:00	1	2.5
18:30	1	2.5
19:00	1	2.5

c. Pest Notification and Repellent

When the PIR sensor detects pest movement, the system activates the buzzer as a pest repellent and displays relevant information on the LCD. During testing, the buzzer sounded for 5 seconds each time a pest was detected, providing a warning to the farmer or system to take immediate action. The LCD also displayed the system status, including the spraying schedule and pest detection status. This allows farmers to monitor greenhouse conditions in real time without the need for manual intervention, which is often time-consuming.

Figure 7. Pest Control System LCD Display

4.2 Analysis

1. Pest Control Efficiency

Testing showed that the developed automatic pest control system successfully improved operational efficiency in detecting and controlling pests in hydroponic greenhouses. By using the PIR sensor, the system can detect the presence of pests in less than 5 seconds, providing a quick response to threats to the plants. This reduces reliance on manual methods, which are often slower and less effective.

2. Effect of Using Plant-Based Pesticides

Automatic spraying of plant-based pesticides proved effective in reducing the number of pests in hydroponic crops. With flexible scheduling through the RTC, the system can adjust pesticide spraying as needed without depending on manual intervention. The system also optimizes the use of plant-based pesticides by minimizing waste, as spraying only occurs when necessary—based on pest detection or preprogrammed timing.

3. Overall System Success

Overall, the developed automatic pest control system performed well and achieved its goal of reducing manual intervention. All components, including the PIR sensor, water pump, RTC, and LCD, functioned properly according to their respective roles. The pest detection success rate of 100% for rats demonstrates the reliability of the PIR sensor in hydroponic farming applications.

This device uses a DC power source; therefore, an adapter is required to convert AC current into DC current with a voltage specification of 12V and a current output of 5A for operating this system.

Using the power equation:

$$P = V \times I$$

Where V and I represent voltage and current, respectively, the power required to operate this system is:

$$P = V \times I$$
$$= 12V \times 5A = 60 \text{ Watts}$$

The energy consumed is calculated as:
$60 \text{ W} \times 0.1 \text{ hour} = 6 \text{ Wh} = 0.006 \text{ kWh/day}$

If the electricity tariff is Rp. 1,500 per kWh, then the system's daily energy cost is:
0.006 × Rp. 1,500 = Rp. 9/day,

so the monthly cost becomes:
Rp. 9 × 30 days = Rp. 270.

This cost is very minimal compared to the benefits gained from using this system. In comparison with traditional pest control methods, this automatic system demonstrates several advantages. Manual pest control often requires a long time, significant labor, and a reliance on chemical pesticides that pose health risks. The automatic system, which utilizes PIR and RTC sensors, can detect pests more quickly, reduce the use of chemical pesticides, and optimize the use of more environmentally friendly plant-based pesticides.

Conclusion

The development of an automatic pest control system for hydroponic greenhouses using Arduino has proven to be effective and efficient. The integration of PIR sensors, RTC modules, water pumps, and LCD displays allows the system to automatically detect pests, spray plant-based pesticides, and provide real-time notifications without requiring constant manual supervision.

Testing results indicate that the system successfully improves pest control efficiency, reduces human intervention, and minimizes the use of harmful chemical pesticides. The flexibility of scheduling through the RTC also ensures optimal pesticide usage, reducing waste and promoting environmentally friendly agricultural practices.

Overall, this system offers a smart, sustainable, and low-cost solution for pest management in hydroponic farming, contributing to increased productivity and the adoption of green technology in modern agriculture.

This study successfully developed an automatic pest control system for hydroponic greenhouses using Arduino. The system is not only efficient in detecting pests but also in managing the spraying of plant-based pesticides. With this system, hydroponic farmers can reduce manual intervention, improve operational efficiency, and optimize the growth of hydroponic plants. This research is expected to contribute to the development of sustainable agriculture.

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