

## Smart Greenhouse Design Based Internet of Things (IoT) With Microcontroller Arduino Uno

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### ABSTRACT

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Technological developments are increasingly rapid. However, it has not spread evenly among the people. Most people still use traditional methods and depend on the uncertain climate to meet their food needs, such as vegetables and fruits. Based on this, an Internet of Things (IoT) based Smart Greenhouse Design with Arduino Uno Microcontroller was created as a solution that is expected to help make it easier for farmers to cultivate plants. The greenhouse is a building that has the function to protect plants from external disturbances such as pests, heavy rain, strong winds, and excessive humidity. Meanwhile, what is called a smart greenhouse that uses technology such as the Internet of Things (IoT), is designed to automatically monitoring uses the Arduino Uno microcontroller as the control center for each sensor used, namely DHT22 (air temperature and humidity sensor), Soil Moisture (soil moisture sensor), GUVA-S12SD (UV light intensity sensor). The sensor will obtain the required data and will be automatically sent to the server (blynk application) with the help of ESP8266 (wifi module). The method used in this study is engineering design in the manufacture of the automation system. The results of this research are in the form of a smart greenhouse that can regulate, adjust, and modify the climate to optimize the conditions and processes of plant growth in the greenhouse equipment through microcontrollers and monitoring devices such as sensors and can be controlled remotely via mobile phones or computers everywhere.

**Keywords:** *design, smart greenhouse, internet of things (IoT), engineering design.*

## 1. INTRODUCTION

The rapid and sophisticated development of today's technology certainly plays a major role in almost every aspect of human life in helping to solve various problems, especially in the agricultural sector [1]. In the modern era of the 4.0 revolution, many advanced technologies have been applied in world agriculture [2]. As seen in large countries, namely the United States, Australia, Japan, Korea, China, the Netherlands, and other countries with sophisticated agricultural technology, one example of its application is to cultivate plants in a modern way using greenhouse technology.

Innovations in agriculture continue to develop and have entered Indonesian territory, especially in big cities where sophisticated technology has been applied to support agricultural production, including the greenhouse technology itself, where greenhouses are used to cultivate horticultural crops such as fruits and vegetables [3].

Greenhouse technology is of course very helpful for agricultural systems in developing countries like Indonesia because climate change that has occurred in recent years has become a major concern, especially in developing countries that have had a major impact on the agricultural sector such as crop failure due to drought. Given the important role of the agricultural sector in the development of developing countries and its status as the backbone of the economy, meeting people's daily needs, alleviating poverty, and creating jobs, the application of greenhouse technology can be an opportunity to overcome the problems that occur [4].

However, the development of this technology has not spread evenly among the public, especially in remote areas. Most people today still use traditional methods and depend on an erratic climate to meet their food needs such as vegetables and fruits [5]. Farmers in remote areas are also faced with challenges when adopting modern technology such as smart greenhouses, this is due to a lack of knowledge and adequate access to information regarding this technology and limited costs [6].

There is a solution to overcome this problem along with innovation in agriculture, namely by utilizing smart greenhouse technology, usually referred to as a smart farming system or smart farming [7]. However,

so far the monitoring and control of the greenhouse system still use manual methods, such as how maintaining moisture in the plants by manually watering and measuring temperature using a thermometer for environmental conditioning [8].

Therefore, utilizing smart greenhouse technology is expected to make it easier for farmers to cultivate crops. The smart greenhouse concept is to regulate, adjust, and modify the climate to optimize the conditions and growth processes of plants in the greenhouse through microcontroller equipment and monitoring devices such as sensors which can be controlled remotely [9]. A system that can be controlled automatically and is not limited by distance with the Internet of Things (IoT) where every device is connected to the Internet so that it can be controlled directly from anywhere and anytime [10].

To support the application of smart greenhouse technology, a participatory approach is needed and involves farmers in the development process and provides better accessibility to technology through outreach and training as well as financial support such as government assistance or business-based financing that can help farmers overcome existing obstacles.

Previously there had been related research that discussed the technology of smart greenhouses.

Previous research designed a greenhouse monitoring system that is expected to increase efficiency in farming and maintain environmental factors that affect plant growth using the prototype method. The research aims to determine plant growth and fertility to get maximum results by using automatic watering technology which is integrated with applications so that it can be accessed in real-time real-timing plant growth based on the data obtained. However, the designed system can only monitor greenhouse conditions and cannot control the system yet [11].

Subsequent research designed a device to automatically control temperature, humidity, and light intensity in a greenhouse for shallot plants using the prototype method. The designed tools can run according to their respective functions and according to planning, but the sensors used are still limited and incomplete [12].

Furthermore, there is research that aims to create tools for monitoring and controlling the microclimate conditions in greenhouses with an IoT platform, namely the Blynk application. Based on the research results, a prototype system and tool can be built and designed to monitor and control the greenhouse microclimate [13].

Designing a prototype of an automatic control system for greenhouses based on Arduino and IoT for chili plants. The circuit works so well that the automated system for chili plants is based. However, details of the greenhouse design are not displayed and no tool kit combines all the components as a whole [14].

There is research that aims to design and create a system to facilitate the cultivation of hydroponic plants using smart greenhouse technology that can be run automatically using Arduino Uno as a microcontroller. Using the prototype method, but he did not explain whether the sensor test was by the system design built for the process of cultivating plants in a greenhouse [15].

Based on the description of the background above, the author raised the title of this study namely "Smart Greenhouse Design Based Internet of Things (IoT) with Microcontroller Arduino Uno."

## 2. METHODS

In developing this smart greenhouse design, the engineering design method is used to make the automation system. The design engineering method is a series of activities that cover the design, development, and implementation processes which in practice lead to new changes in the form of processes or products, this method will produce automation tools that are structured and focus on each stage of the process [16].

The stages of the research include the steps for carrying out the research to be taken starting from the beginning to the end as described in Figure 1.

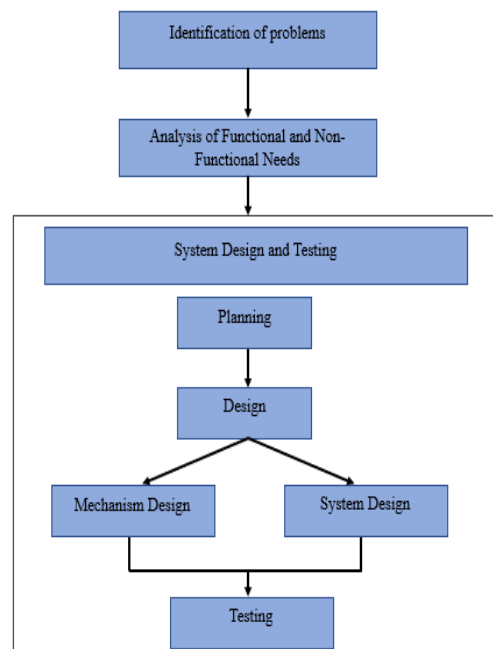


Figure 1. Research Stages

### 2.1. Identification of problems

In the first stage, namely problem identification, researchers identify problems encountered in the field such as unstable weather factors affecting the fulfillment of food needs such as vegetables and fruits so breakthroughs are needed in agricultural systems by utilizing smart greenhouse technology.

### 2.2. Analysis of Functional and Non Functional Needs

This stage is to identify the needs before designing the tool. In designing a smart greenhouse, the functional and functional requirements in this study include electronic and mechanical components. In addition, the concept of the Internet of Things (IoT) is very important in tool design. The components needed are an Arduino Uno which functions to control the temperature and humidity sensor (DHT22) and an ultraviolet intensity sensor (GUVA-S12SD) which functions to acquire data on microclimate conditions in the greenhouse, as well as a soil moisture sensor (Capacitive Soil Moisture).

### 2.3. System Design and Testing

System design and testing are the stages for designing an Internet of Things (IoT)-based smart greenhouse controlled by a microcontroller. The beginning of this stage is to carry out the overall system planning process

by preparing the tools and materials needed. After that proceed to the system design process where the design process is divided into two parts, namely the mechanism design and system design.

### 2.3.1. System Design

The system design process aims to provide an overview of the smart greenhouse design that will be developed. The system design includes mechanical design for the greenhouse frame using Sketchup software, hardware design using Fritzing software, and smart greenhouse code design using Arduino IDE software.

### 2.3.2. Mechanism Design

Mechanism design aims to develop the flow and workings of the system to be designed. The mechanism design includes the design of a block diagram along with how the smart greenhouse system works which is explained using a flowchart.

### 2.3.3. Testing

System testing is needed to find out how the designed system works well according to expectations based on certain parameters. In this study, several tests were carried out, namely as follows:

- a. Testing of monitoring and controlling devices

The testing process is carried out on each device which aims to find out whether the Arduino Uno microcontroller is integrated with sensors and can carry out monitoring and automation processes properly. Tests are carried out by monitoring the greenhouse according to the function of each device whether the device can work according to its function such as reading the values of temperature, humidity, soil moisture, and UV, radiation intensity.

- b. Testing the sending data from sensor monitoring results

This test aims to determine the completeness of the data sent to the server. The testing process was carried out with monitoring and automation experiments on Arduino Uno with the help of ESP8266 sending sensor monitoring results in data via wireless to the server.

## 3. RESULTS AND DISCUSSION

This section describes the design of the tool which consists of mechanical design, electronic circuit design (hardware), and software design, as well as how the smart greenhouse system works, data display on the server, and the result of the test.

### 3.1. Research result

#### 3.1.1. Tool Design

Tool design consists of three main parts, n:mechanical design, electronic design (hardware), and software design (software).

#### 3.1.2. Mechanical design

The mechanical design process uses Sketchup software to design the greenhouse frame. The greenhouse framework needed is as follows:

1. Ingredients
  - a. Iron for greenhouse framework (zinc battens, channel c, foll ceiling)
  - b. Bout rilling
  - c. UV plastic for walls and roofs
  - d. Glue
2. Size
  - a. Length: 5 meters
  - b. Width : 3 meters
  - c. Height: 2.50 meters
3. Greenhouse model: gable

The greenhouse frame design can be seen in Figure 2

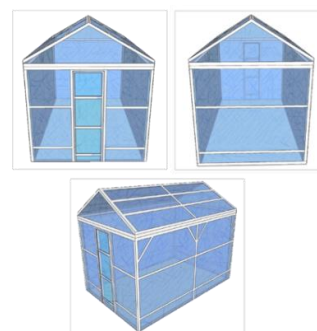


Figure 2. Design of a greenhouse frame

#### 3.1.3. Hardware Design

Hardware design begins with making block diagrams followed by electronic circuit design using fritzing. The block diagram for designing a smart greenhouse based on the Internet of Things (IoT) with the Arduino Uno microcontroller is shown in Figure 3.

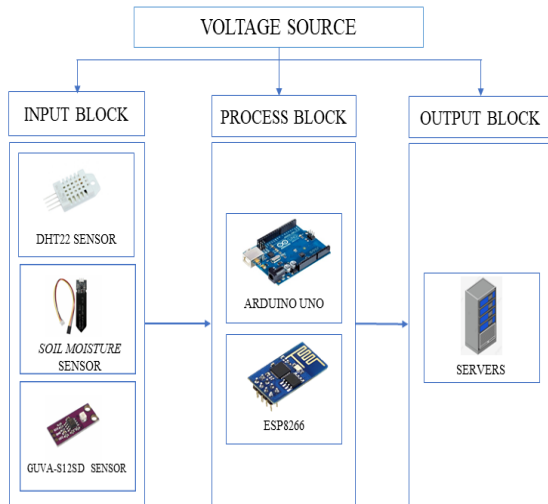


Figure 3. Block Diagram

The following is an explanation of the block diagram in Figure 3.

a. Voltage Source Block (Power Supply)

The power supply block functions to supply voltage to each block, namely the input block, process block, and output block [22].

b. Input Block

In the design of the input block as shown in Figure 3 several sensors and components will work according to their respective functions. The following are the components contained in the input block.

1. Temperature and humidity sensor (DHT22)

This sensor functions to measure and detect the humidity and temperature of the air in the greenhouse [17].

2. Soil moisture sensor

Soil moisture sensors are used to measure water content and soil moisture in plants [18].

3. Ultraviolet light intensity sensor (GUVAS12SD)

GUVAS12SD sensor as an ultraviolet light detector in a greenhouse [19].

c. Process Block

There are two types of microcontrollers in the process block design namely.

1. Arduino Uno

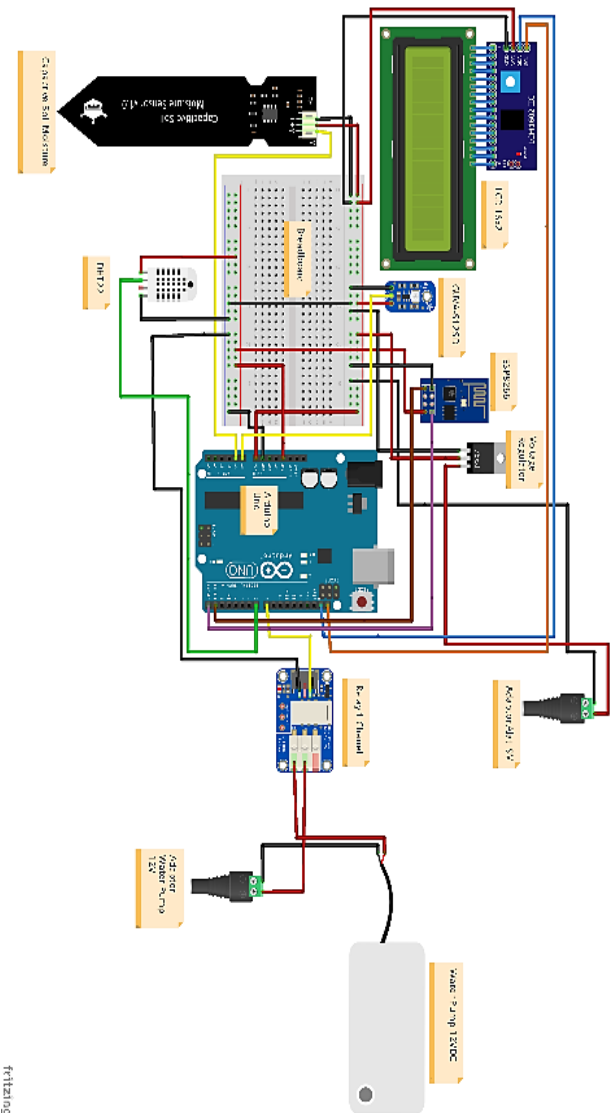
Arduino Uno functions to read sensor data and then send the data to the server via the internet with the help of the ESP8266 [20].

2. ESP8266

The wifi module (ESP8266) is an Arduino enhancement to connect to the internet network (wifi) [21].

d. Output Block

In Figure 3 there is an output block design in the form of results obtained from the process block, namely the server. The server functions to store and accommodate sensor data sent by Arduino Uno with the help of the ESP8266 module which will later be displayed on the Blynk application so that it can be used by users to monitor and control greenhouse systems. The following is an electronic circuit design using fritzing.



fritzing

Figure 4. Electronic circuit design (hardware)

Pin descriptions and each component in Figure 4 can be seen in Table 1 and Table 2.

Table 1 Description of electronic circuit pins (hardware)

Cable Color	Pin
Red	VCC (Voltage)
Yellow and green	Data
Black	Ground (Negative Pole)
Brown	TX
Purple	RX
Blue	SDA
Orange	SCL

Table 2 Description of components and circuit pins

Sensors/Components	Arduino pins
	VCC
DHT22	GND
	D7(Arduino)
	VCC
GUVA-S12SD	GND
	A0 (Arduino)
	VCC
Soil Moisture	GND
	A1(Arduino)
	VCC
Relay	GND
	D8 (Arduino)
	VCC
ESP8266	GND
	TX
	RX
	VCC
LCD	GND
	SDA
	SCL

The design of electronic circuits is designed using fritzing software. Figure 4 is a schematic combination of each hardware component as a whole. In Figure 4 Arduino Uno is the main component in controlling and controlling sensors. ESP8266 receives input from Arduino and processes the data and then sends it to the server (blynk) using wireless media.

A more detailed explanation can be seen in Figure 5.

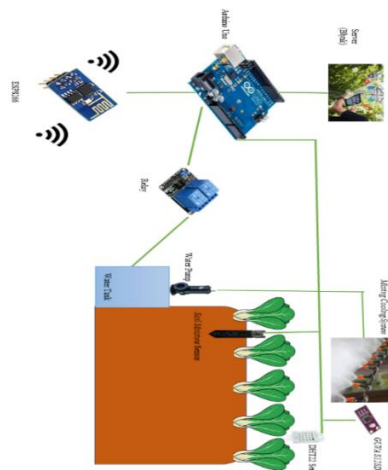
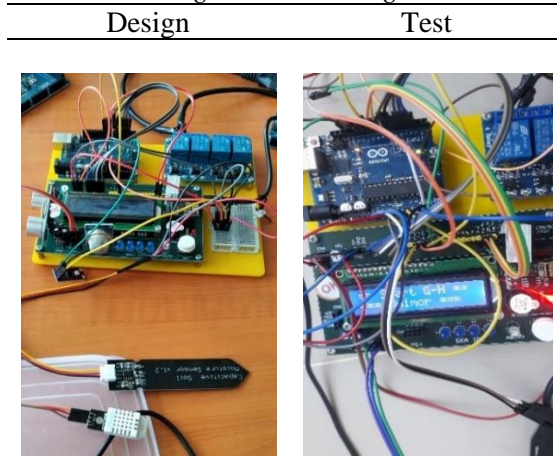


Figure 5. Smart greenhouse control components

Based on Figure 5, it can be seen how the components in the greenhouse work together, there is an Arduino Uno as the control center for sensors namely DHT22 which functions to detect temperature and humidity in the greenhouse room, then soil moisture sensors which are in charge of detecting soil moisture in plants and sensors GUVVA-S12SD to measure the index and intensity of ultraviolet light intensity in a greenhouse. Then the relay is an electronic switch whose job is to control the water pump automatically to turn on the misting cooling system. The misting cooling system functions to help lower the air temperature. This is because when water vapor in the form of fog evaporates, the air will become cooler. The water pump will work and take water from the reservoir and flow it through the hose that has been connected and installed with a spray nozzle. The high-pressure water pump allows water to come out of the spray nozzle in the form of small-diameter droplets like mist. This helps the cooling process and keeps the indoor temperature of the greenhouse at a lower level. All sensors and components such as relays and ESP8266 as additional devices that help Arduino in sending data via wireless to the server (blynk) are connected to Arduino Uno. When the DHT22, soil moisture, and GUVVA-S12SD sensors are turned on, data such as temperature and humidity, soil moisture, and UV light intensity will be sent to the server (blynk) to be monitored and taken control measures such as turning on a misting cooling system to help control temperature. in greenhouses.



Table 3. The process of designing and testing monitoring and controlling devices



The testing process is carried out to find out whether each component in the smart greenhouse series can work properly as expected, as shown in Table 4.

Table 4. Test results for monitoring and controlling devices

No	Device Name	Testing	Status		Results
			Succ ess	Fa il	
1	Arduino Uno microcontroller	Program uploads	✓	-	On
2	ESP8266	Send data to the server	✓	-	On
3	Soil Moisture sensor	Take the soil moisture value	✓	-	On
4	DHT22 sensor	Take the temperature & humidity values	✓	-	On
5	GUVA-S12SD sensor	Take the intensity value of the ultraviolet light	✓	-	On

Table 4 continued...

No	Device Name	Testing	Status	Results
6	LCD 16x2	Display Information	✓ -	On
7	Relay	Switch On/Off	✓ -	On
8	Water Pump	Relay On water pump On	✓ -	On

Based on the results of monitoring and controlling device testing, it was found that each component can work and function properly.

a. Testing the delivery of data from sensor monitoring results

The test results are generated by the sensor by using an automatic water pump for the misting cooling system. The results of data collection for DHT22, soil moisture, and GUVA-S12SD sensors for one day starting from 10.00 WITA to 00.00 WITA is shown in Table 5.

Table 5. Data from sensor monitoring results

Date	Time	Temperature	Air humidity	UV intensity	Soil moisture
31/08/2022	10.00	33°	87%	134	255
	11.00	33°	98%	116	255
	12.00	35°	65%	103	255
	13.00	42°	70%	90	255
	14.00	42°	59%	92	255
	15.00	38°	62%	59	255
	16.00	38°	59%	93	255
	17.00	29°	93%	55	255
	18.00	26°	99%	40	255
	19.00	26°	99%	40	255



Table 5 continued...

Date	Time	Temperature	Air humidity	UV intensity	Soil moisture
31/08/ 2022	20.00	25°	99%	39	255
	21.00	24°	99%	39	255
	22.00	24°	99%	40	255
	23.00	24°	99%	40	255
	00.00	23°	99%	39	255

Table 5 is the result of data collection on the greenhouse in one day, the process of monitoring air temperature and humidity with the DHT22 sensor, ultraviolet light intensity using the GUVA-S12SD sensor, and soil moisture using the capacitive soil moisture sensor which is done every hour.

Based on the readings, the temperature and humidity sensors, and the intensity of the ultraviolet light sensor, have increased from morning to noon and began to decrease in the afternoon to evening. While the soil moisture data remained the same after watering.

The display of data on the server can be seen in Figure 8.

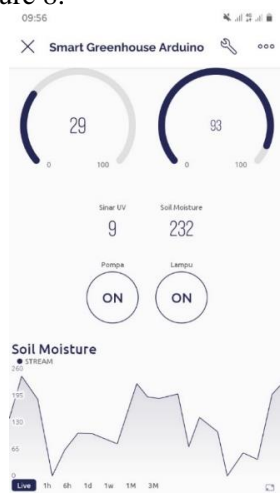


Figure 8. Server view (blynk)

Figure 8 is a server display (blynk) where data from each sensor can be seen. This makes it easy to monitor and take the necessary actions to control the state of the greenhouse

from anywhere and at any time as long as it is connected to the internet.

## CONCLUSION

After conducting the research process, it can be concluded that the smart greenhouse design using the Internet of Things (IoT) concept can automatically run well. The designed program can also work as expected, such as sending data to the server, displaying temperature and humidity data, ultraviolet light intensity and soil moisture in real-time, and temperature conditions in the greenhouse using a misting cooling system. Using the ESP8266 can help Arduino Uno send monitoring data to the server to make it easier to control greenhouse conditions from anywhere and at any time as long as it is connected to an internet network.

Based on the results of this study, several suggestions can be used to develop further research, namely as follows. (1).Ventilation can be added to the greenhouse building to facilitate air circulation inside. (2).Adding a water filter so that the misting cooling system can run smoothly and is not clogged. (3). Ensure that the internet connection used is good so that it can support sending sensor data to the server. (4). Adding a water level sensor to monitor the water level in the tank if it runs out.

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