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Research Original Article

Type Design of Control System in Hydroponic Plants Based on Arduino Uno

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Abstract
The decreasing availability of agricultural land due to urbanization threatens farmers' income and agricultural sustainability. Hydroponic cultivation offers a solution by maximizing limited land, especially in urban areas. However, challenges in managing nutrients and watering systems remain a key research focus to enhance hydroponic efficiency and support environmental sustainability and food security. This research aims to control water flow, watering, and nutrition based on a schedule regulated by the RTC DS3231 and to manage the water volume in the reservoir using the HC-SR04 sensor. Based on data analysis and testing, it is concluded that the system operates effectively, regulating water flow from 08:00 to 17:00 at a flow rate of 0.001464 m^3/s, watering pests at 09:00 and 17:00 for 5 minutes at a flow rate of 0.0016 m^3/s, providing nutrients every three days at noon for 2 minutes at a flow rate of 0.0007917 m^3/s, and managing water volume in the reservoir between a minimum of 92% and a maximum of 97%, with a total capacity of 5,214 liters. This system works well, allowing the owner/farmer to only monitor the hydroponic plants.
Keywords: Limited Land, Hydroponics, Urban Agriculture

Introduction
Limited agricultural land is a major problem for farmers, especially with the decreasing land area and soaring land prices [1], [2]. This makes it increasingly difficult for farmers to have gardens to grow vegetables [3], [4]. The decrease in the amount of productive land occurs due to the conversion of agricultural land into residential land due to increasing population density [5]. As a result, many farmers have switched to other professions to meet their economic needs. This situation has an impact on decreasing agricultural output, especially in the provision of food in an area. Therefore, the availability of food must be maintained to meet the food needs of the community [6].

To overcome the problems faced by the community related to limited land, the hydroponic method can be an effective solution in vegetable cultivation [7]. Hydroponic farming does not require a large area because it can be done in the yard or other limited areas, especially in dense urban areas and lack of empty land for farming [8], [9].

potential problems that often occur when cultivating hydroponic plants manually are incorrect water doses [10]. Controlling water flow, water volume, watering, and handling pests and nutrients in hydroponic systems is still often done manually or conventionally [11], [12]. This process requires a lot of time and energy because each aspect must be checked and adjusted one by one to ensure optimal conditions for the plants [13]. To facilitate the management of water and nutrients in hydroponic systems, this study developed a system that can monitor and control nutrients, watering, and water volume [14].

The advantages of the hydroponic system include minimal land requirements, relatively easy maintenance, and high nutritional value and product sales value. This method produces higher production with uniform products and more guaranteed quality, especially in terms of hygiene and safety.

Materials & Methods

The research on the Design and Development of a Control System for Hydroponic Plants Based on Arduino Uno [15]-[18] was conducted in the odd semester, from October 2023 until completion. The study was carried out in Muara Dua District, Lhokseumawe, Aceh Province. This location was chosen to facilitate the assembly process of the system and data collection for the development of the system, ensuring that the research proceeded smoothly.

The data collection methodology through observation journals and articles involves a systematic process for gathering relevant and high-quality information. First, through observation journals, the researcher directly observes the phenomenon under study and records significant observations.

These observations can occur in various contexts, ranging from direct field observations to observations within specific environments. Meanwhile, through articles in journals, the researcher utilizes published literature sources to gain deeper insights into the research topic. By leveraging both approaches, the researcher can achieve a comprehensive and in-depth understanding of the phenomenon studied, thereby supporting the validity and reliability of their research findings.

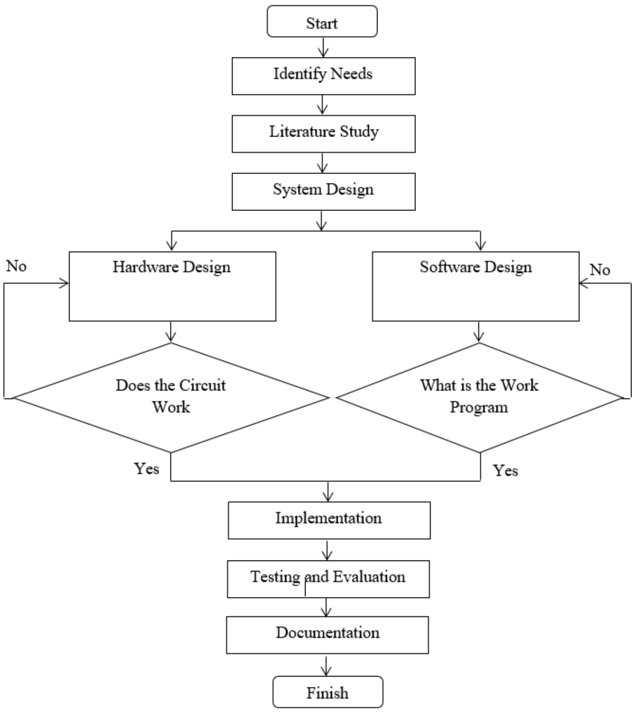

Figure 1. Research flow chart

The need for tool planning is an important first step in successful tool development, as it helps ensure that all parties involved have a clear understanding of what is desired and expected from the tool. In the assembly of "Design and Construction of Control Systems for Hydroponic Plants Based on Arduino Uno" components and equipment are needed to facilitate the assembly process later. Some of the tools and materials needed can be seen in the tables below:

Table 1. Components to be used

No	Component	Amount
1.	Arduino Uno	1
2.	Bilge Pump Water Pump	3
3.	Relay 4 Chanal	1
4.	MCB 1 Phase	1
5.	Power Supply 12V 10A	1
6.	LM2596	1
7.	RTC DS3231	1
8.	Sensor HC-SR04	1
9.	Saklar Switch	1
10.	LCD I2C 16x2	1

Table 2. Materials to be used

No	Material	Amount

1.	3-inch pipe	3,5 Meter
2.	1/2 inch pipe	3 Bars
3.	Connecting Cable	enough
4.	Mist Nozzle Head Sprayer	4 Pieces
5.	Elbow	45 Pieces
6.	3-inch Pipe Cap	6 Pieces
7.	Pipe Glue	1 Piece
8.	Saw	1 piece
9.	Solder	1 piece
10.	Meter	1 piece
11.	Acer Aspire	1 piece
12.	Storage Container	3 Pieces
13.	Clear Hose	3 Meter
14.	Multimeter	1 Piece
15.	Terminal Block	1 Piece
16.	Spacer	15 Pieces
17.	Panel Box	1 Piece
18.	1-inch Pipe Doop	2 Pieces
19.	Screwdriver + -	1 Piece
20.	Isolation	1 Piece
21.	Faucet	1 Piece
22.	Laptop Acer Aspire A314-33	1 Unit
23.	Cutter Knife	1 Piece
24.	Cable Ties	enough
25.	Clear Elbow	3 Pieces
26.	Clear Tedos	1 Piece
27.	Todos Pipe 1/2 inch	12 Pieces
28.	Salttip	1 Piece

2.1 Electrical Design

Electrical design is the process of planning and developing electrical systems or electronic circuits to meet specific needs [19]. The electronic design includes several components such as a switch, power supply, LM2596, Arduino Uno, ultrasonic sensor, 16x2 I2C LCD, RTC, 4-channel relay, and water pump. The overall operation of the device is as follows:

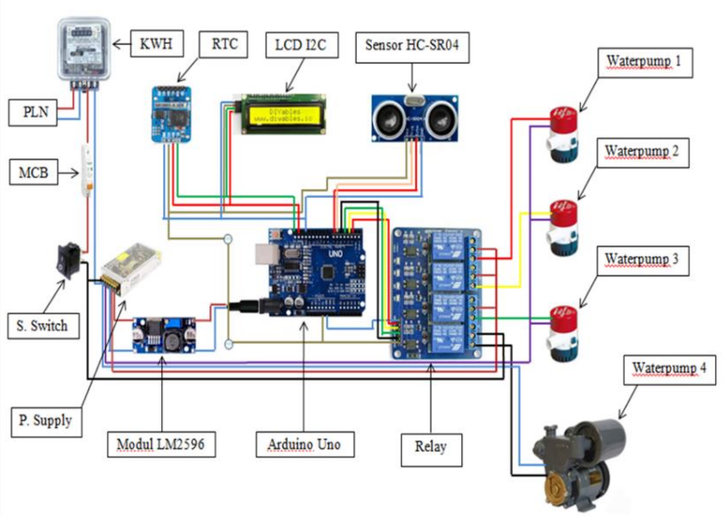

Figure 2. Overall electrical wiring diagram

2.2 Mechanical Design

The mechanical design in this study is in the form of a planting system with a hydroponic system plantation. This ensures that all physical components are well integrated and function according to project specifications. In addition, it helps protect equipment from weather elements, design safe berthing, and create a physical environment that supports operations [20].

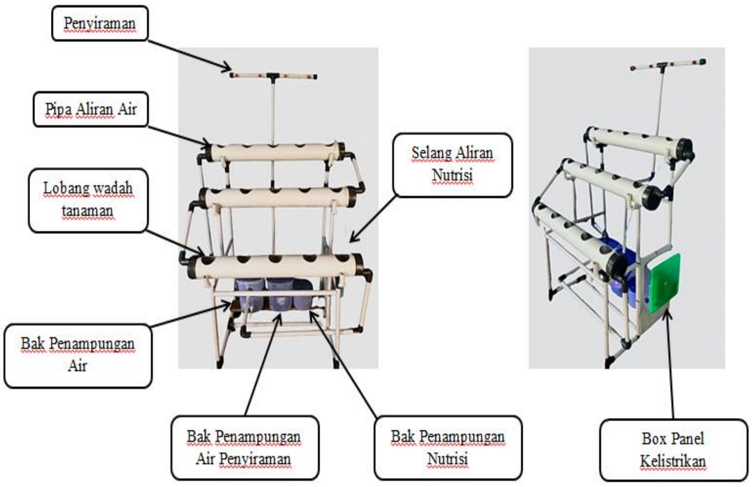

Figure 3. Mechanic design

2.3 Programming

The overall programming results using the Arduino IDE software are very important to ensure that the system that has been designed and implemented using Arduino Uno can function optimally according to the previously determined needs [16]. In the image below there is a picture of the programming results but the entire programming is in the attachment. The following are the programming results on hydroponic system plants.

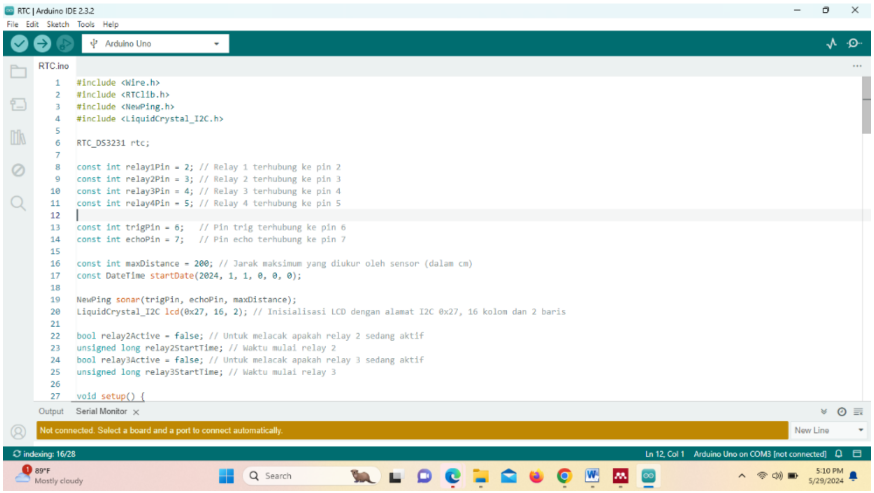

Figure 4. Control system design program

Results and Discussion

The Control and Monitoring System in a hydroponic farming setup is designed to regulate water flow in the piping installation, pest watering on leaves, nutrient delivery, and increasing water volume in the reservoir. The results of the Control and Monitoring System design for hydroponic farming will include the outcomes of the electrical design, mechanical design, and the testing process for each component.

3.1 Power Supply Testing Results

In this test, the first step is to provide an input voltage of 220 Volt AC from the PLN power source. The power supply then converts this AC voltage into the desired DC voltage, which is 12 Volt. The following are the results of the power supply testing that will be conducted:

Table 3. Power Supply testing results

No	Component	Input	Output	Status
1.	Power Supply	AC 220 Volt	DC 12 Volt	Good

Figure 5. Power supply measurement results

3.2 LM259 Module Test Results

In this test, it is expected that the output of the LM2596 Module matches the output values required by all modules and sensors used in this study. The following is the testing procedure for the LM2596 Module that will be carried out:

Table 4. LM2596 module test results

No	Component	Input	Output	Status
1.	Modul LM2596	DC 12 Volt	DC 7 Volt	Good

Figure 6. Measurement results on the LM2596 module

3.3 Testing of RTC DS3231 and Water Pumps 1, 2, and 3

The testing of the RTC DS3231 aims to schedule Water Pumps 1, 2, and 3 according to the commands set on the RTC DS3231. The following is the testing procedure for the RTC DS3231 and the water pumps:

Table 5. DS3231 RTC test results

No	Component	Scheduling	Order	Status
1.	RTC DS3231	08:00 to 17:00	ON	Good
2.	RTC DS3231	09:00 and 17:00 For 5 Minutes	ON	Good
3.	RTC DS3231	Every Three Days At 12:00 For 1 Minute	ON	Good

Table 6. Waterpump test results 1,2 and 3

No	Component	Scheduling	Order	Status
1.	Waterpump 1	08:00 s/d 17:00	ON	Good
2.	Waterpump 2	09:00 and 17:00 For 5 Minutes	ON	Good
3.	Waterpump 3	Every Three Days At 12:00 For 1 Minute	ON	Good

3.3.1 Water Pumps 1

The following are the test results of Waterpump 1 at 08:00 to 17:00 which functions to flow water in the piping installation in hydroponic plants.

Figure 7. Waterpump 1 trial results at 08:00 to 17:00

3.3.2 Water Pumps 2

The following are the test results on Waterpump 2 at 09:00 and 17:00 which functions to water plants from pests that can damage plants.

Figure 8. Waterpump 2 trial results at 09:00 and 17:00

3.3.3 Water Pumps 3

Here are the testing results for Water Pump 3 at 12:00, which is used for delivering nutrients to the hydroponic plant system.

Figure 9. Results of water pump 3 testing every 3 days at 12:00

3.4 Testing Results for HC-SR04 Sensor and Water Pump

The testing of the HC-SR04 sensor aims to provide commands to Water Pump 4 to add water volume to the tank. The following outlines the testing procedure for the HC-SR04 sensor and the water pump:

Table 7. HC-SR04 sensor testing results

No	Component	Water Volume	Status
1.	Sensor HC-SR04	92%	Good
2.	Sensor HC-SR04	98%	Good

Figure 10. Results of sensor experiments at water volumes of 92% and 98%

Table 8. Water Pump Testing Results 4

No	Component	Water Volume	Order	Status
1.	Waterpump 4	92%	ON	Good
2.	Waterpump 4	98%	ON	Good

Figure 11. Water pump testing results 4

3.5 Testing Results for HC-SR04 Sensor and Water Pump

Testing of the 16x2 LCD I2C Module, which is used to monitor the output of the module. The following outlines the testing procedure for the 16x2 LCD I2C Module:

Table 9. 16x2 LCD I2C module testing results

No	Komponen	Order	Status
1.	Modul LCD I2C 16x2	ON	Good

Figure 12. 16x2 LCD I2C module testing results

Conclusions

After conducting the Testing and Analysis above, it can be concluded as follows:

1. Based on the results of the water flow control system test from 08:00 to 17:00, it can be concluded that the system works well using the RTC DS3231 with a flow rate of 0.001464 m3/s or 1.466 L/s.
2. Based on the results of the pest control system test carried out at 09:00 and 17:00 for 5 minutes, it can be concluded that the system works well using the RTC DS3231 with a watering rate of 0.0016 m3/s or 0.16 L/S.
3. Based on the results of the nutrient control system test carried out every 3 days at 12:00 for 2 minutes, it can be concluded that the system works well using the RTC DS3231 with a nutrient flow rate of 0.0007917 m3/s or 0.7917 L/s.
4. Based on the results of the air volume control system test in the reservoir using the HC-SR04 sensor, it can be concluded that the system works well. The test results show that the lowest air volume detected is 92% of the reservoir capacity, while the highest air volume is 97% with an air volume in the reservoir of 5,214 liters.

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