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Development of Prototype a Nutrient Automation System for Hydroponic System

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Abstract: Nutrients are essential for their use in the process of plant growth. However, the usage of the concentration of the nutrients must be controlled because it can damage the plant. In order to do so, the quantity of nutrients is evaluated before it is fed to the plant. Automatic mixer can save so much energy in mixing the nutrients. Human energy are no longer needed in mixing the nutrients. Overall, this project discussed about the development of prototype a nutrient automated system for hydroponic which was accessed by the sensor to detect the overuse of the nutrients. The major parts of this project consists of mixer and electrical conductivity (EC) sensor. The nutrients solution are the combination of water and AB nutrients. The mixer was controlled by the DS3231 Real Time Clock (RTC) module where the motor of the mixer is triggered by single channel relay at the desired time to operate. The DS3231 RTC module will keep the accurate date for the system. The amount of nutrients usage was monitored in the serial monitor of Arduino IDE software. The data for the timer settings was kept inside the Arduino IDE software which the system will operated at desired time as long as the mixer is supplied by power. Based on the results, the system are success to detect the temperature is 25◦C, 0.06 ~ 0.09ms/cm EC of water. Beside that the EC for nutriet is average 7.29ms/cm or 4608ppm with the temperature is 25◦C.

Keywords: Nutrient, Arduino, Hydroponic

1. Introduction

Agriculture is a sector where involving large fields, large resources inputs such as fertilizer and pesticides, and modern mechanization [1]. The agricultural sector has existed since the rise of human civilization a thousand years ago. Many regions in the world are developing based on agriculture where this sector is one of the largest in food production. There is a massive change to the agricultural practice in the 20th century which particular to the agriculture chemical. Many departments related to the agricultural chemical which includes the application of chemical fertilizer, chemical insecticides and fungicides, nutritional needs for the animal, and many more. Nowadays, nutrient plays an important role in the agriculture practice where the used of nutrients can contribute harm to the environment condition and human health Nutrients are the most important elements to plant growth. Three primary micronutrients in which nitrogen (N), phosphorus (P), and potassium (K) are the main element because

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of its relativeness to plants in agricultural production. The use of these three main micronutrients can have adverse effects on the environment and plant growth itself if the level of micronutrients is found too excessive (toxic) or inadequate (low) [2]. The quantity of the nutrients that will be feed to the plant should be enough to keep the concentration of the nutrients on the right quantity. There was a research that had been done which to sense the nutrients element and one of the research was 2 automated sensing of hydroponic micronutrients using a computer-controlled system with an array of ion selected electrode. An ion-selective electrode (ISEs) is the approach that has been used which can directly measure the analyte with a wide range of sensitivity and are small and portable [3]. Agriculture is a sector where involving large fields, large resources inputs such as fertilizer and pesticides, and modern mechanization [1]. The agricultural sector has existed since the rise of human civilization a thousand years ago. Many regions in the world are developing based on agriculture where this sector is one of the largest in food production. There is a massive change to the agricultural practice in the 20th century which particular to the agriculture chemical. Many departments related to the agricultural chemical which includes the application of chemical fertilizer, chemical insecticides and fungicides, nutritional needs for the animal, and many more. Nowadays, nutrient plays an important role in the agriculture practice where the used of nutrients can contribute harm to the environment condition and human health Nutrients are the most important elements to plant growth. Three primary micronutrients in which nitrogen (N), phosphorus (P), and potassium (K) are the main element because of its relativeness to plants in agricultural production. The use of these three main micronutrients can have adverse effects on the environment and plant growth itself if the level of micronutrients is found too excessive (toxic) or inadequate (low) [2]. The quantity of the nutrients that will be feed to the plant should be enough to keep the concentration of the nutrients on the right quantity. There was a research that had been done which to sense the nutrients element and one of the research was 2 automated sensing of hydroponic micronutrients using a computer-controlled system with an array of ion selected electrode. An ion-selective electrode (ISEs) is the approach that has been used which can directly measure the analyte with a wide range of sensitivity and are small and portable [3]. The traditional agriculture process requires more energy to produce, prepare, and transport food [4].

2. Theory and Project of Nutrients in Agriculture

The explanation of the project will be divided into two main parts which are the theory of the related topic which more focusing on the nutrients part, and the previous study of the project that had been done. Lastly, based on the information gained from the previous study which could lead to the process of learning in improving the project and help to solve the problems related to the studies.

2.1 Theory of Nutrients in Agriculture

The nutrients are essential for plant growth. Other than oxygen and water, the plant also needs nutrients to be absorb just like the human being that needs food to keep on living. In agriculture production, there is a lot of nutrients element that is needed for the plants. Heat, light, and water play an important role in plant production where it should need to appropriately supply to utilize the nutrients efficiently. There are four categories of the nutrients of essential elements of plant growth which are basic nutrients, primary micronutrients, secondary micronutrients, and micronutrients[2].

Two types of fertilizers are commonly used in agriculture production which are organic fertilizer and inorganic fertilizer. The organic fertilizer is created by the animal manure. The use of organic fertilizer could lead to such negative effects if this kind of fertilizer is not properly managed. Imbalance used of manure could affect the water quality which could lead to erosion and bad condition of the soil. Inorganic fertilizer is a synthetic type of nutrients where this fertilizer is more cost-effective and more concentrated. But, the use of inorganic fertilizer could give a similar negative impact as the organic fertilizer if not properly managed [2]. It is really important to know the number of nutrients that should be fed to the plants because there are a variety of plants where needs a specific range of the number of nutrients based on their types. The excessive use of nutrients can cause environmental harm which could affect the air and water quality.

Harmful Algae Blooms (HABs) is one of the concerns which could lead to the harm of the environment and even human health. Most of an algae species is not harmful, but the use of a high amount of nutrients will overfeed the algae, and creating algal blooms that can decrease the oxygen in water, blocking the sunlight and potentially produce toxins. There are three examples of HABs that are known which is Cyanobacteria, Red Tide, and Ciguatera [2].

2.2 Development of Water and Nutrients of Agriculture

Based on the previous research, the researcher in paper [5], discussed a construct a water pumping system powered by a photovoltaic cell which capable to supply water through the desert in Jordan. A mathematical model has been developed in the simulation based on real measurement represented by motor torque to test the performance of the slip of motor with different frequencies. Next, the researcher in paper [6] explained about the stand-alone photovoltaic water pumping system has been designed and modelled for rural and irrigation purposes. A 4.494kW of the PV array has been designed where one PV module was developed by 90 series of solar cells and 2 parallel of solar cells. The paper [7] was explained about the automatic drip irrigation powered by solar will be implemented for the dwarf cherry trees at Zile Distinct of Tokat Province of Turkey. The researcher in paper [8] was explained about the target for the system to be operated was located at a paddy field where the place may take several hundred hectares.

M. Dursun et. al. in [9] was a study about the importance of the quality of spraying which operates in real-time in the application of herbicides based on the direct injection system. In this project, an electrical conductivity (EC) sensor was used. EC sensor is a sensor that can conduct the electric current. The customized sensor was installed at the nozzle to measure the mixture concentration. To measure the response time in the spraying system, the smart conductivity sensor was designed by using the direct injection of pesticides. J. Uddin et. al. in [10], a sensor module that could use to determine the concentration of nutrient in water solution. An electrical conductivity (EC) sensor was used for the measurement of the concentration of the water with a three-inverter oscillator. Next, V. A. Oliveira et. al. [11], a hydroponic system of the Nutrient Film Technique (NFT) was developed. There was a concern in many parameters such as water temperature, pH level, water level, and the concentration of the nutrients. Microcontroller with Wi-Fi ESP8266 is used as a communication medium by using a Wi-Fi network and set to the actuators and sensors. Both the EC sensor and TDS sensor was used in the system. So, the monitoring system is developed which can monitor the pH and PPM values in the Webpage where can overcome the challenge to the farmers. The research in paper [12], the combination of fertilizer and the water were mixed manually to get the solution of the concentration of nutrient. Then, to indicate the electrical conductivity (EC) on the concentration of the nutrients, a TDS sensor was used which is important in crop production. The TDS sensor was assembled with the Arduino Uno R3 board with an ATMega 328 microcontroller. MG996R servo motor actuator was used to control the closed and opened the faucet head. The water level sensor which is SHARP GP2Y0A21 also implemented with the Arduino Uno R3 which to detects the nutrients solution water level and then will be detected by the TDS sensor when the water level is sufficient to immerse the TDS sensor plate.

3. Methodology of Project

In this part, all the processes were shown on how the project will be completed based on the planning that has been decided. This is also the part where all the explanations of theory and list of the components were being included which help to accomplish all the parts related to the development of the project.

3.1 Process of Project

In this project, the components that will be used for the hardware development consist of Arduino Uno, a water pump, a EC sensor, and DS3231 Real Time Clock. The block diagram of the system shown in Figure 1 is based on software and hardware development. The use of DS3231 Real Time Clock is to show the time and date accurately and at the same time control the operation of the mixer motor. The

sensor will be placed inside the tank of the nutrients solution after the nutrients are completely mixed. The probe of the EC sensor will be used to detect the level of nutrients concentration based on the conductivity of the nutrient. The Arduino IDE serial monitor will display the amount of the nutrients based on the EC readings. The details of the specification of the components that will be used for the hardware and also the software used for the circuit and design of the hardware will be discussed on the next topic.

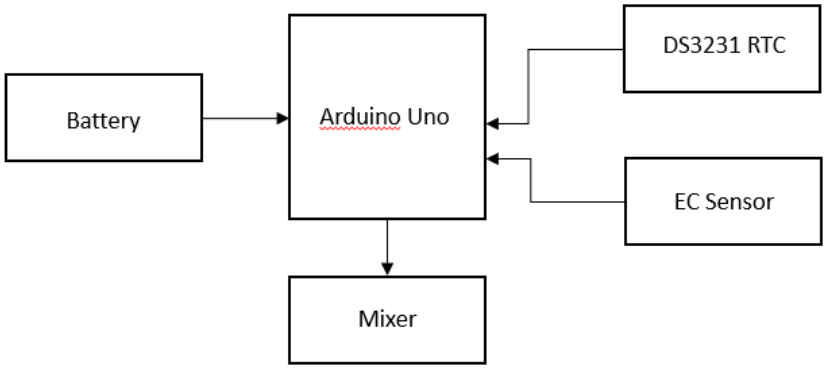


Figure 1: Block diagram of the system

3.2 The main components of the Project

In this part, the component from software and hardware will be explained and discuss to complete this project. The hardware components that will be used are the Arduino Uno microcontroller, DS3231 Real Time Clock, and electrical conductivity (EC) sensor. The software components that will be used is the Arduino IDE, Fritzing, and SketchUp.

(a) Arduino Uno Board

Arduino Uno is a microcontroller board based on 8-bit ATmega328P microcontroller. The microcontroller also consists of a crystal oscillator, serial communication, voltage regulator, and many more including ATmega328P. Arduino Uno has 14 digital output/input pins, 6 analog input pins, a USB connection, a power barrel jacket, an ICSP header, and a reset button. Figure 2 shows the Arduino Uno[13].

Figure 2: Arduino Uno Board

(b) $12V_{dc}$ Motor

DC Motor is the load which will be used for the mixer. This DC Motor is the typical DC brush without a gearhead that usually can be found in a toy car. The supply voltage for the motor is 12V DC. Figure 3 shows the DC Motor[14].

Figure 3: 12V DC motor

(c) DS3231 Real Time Clock Module

DS3231 Real Time Clock is a module that can maintain and count the exact time and date. This module also can show the months and years information. This module is run by a battery. It can work either in 3.3V or 5V which suitable for the microcontroller Arduino Uno. The battery that will be used is a CR2032 3V battery which is the typical battery that can maintain the time information for more than a year. Figure 4 shows the DS3231 RTC that will be used. [15].

Figure 4: DS3231 real time clock module

(d) Single Channel 5V Relay Module

Single Channel 5V Relay Module can control high voltage or high current load such a motor, solenoid valves, or lamps. It is designed to interface the microcontroller which is Arduino Uno that will be used for this project. The terminal is ready with a screw terminal. Figure 5 shows the Single Channel Relay that will be used for this project [16].

Figure 5: Single channel relay module

(e) Electrical Conductivity (EC) Sensor

This is the sensor that will detect and measure the concentration of the nutrients solution. The probe of the sensor can be used to measure the electrical conductivity from the solution and also the ion concentration of aqueous samples. It will be set from the microcontroller to detect the excessive amount of nutrients concentration. Figure 6 shows the electrical conductivity (EC) sensor which will be used for this project [17].

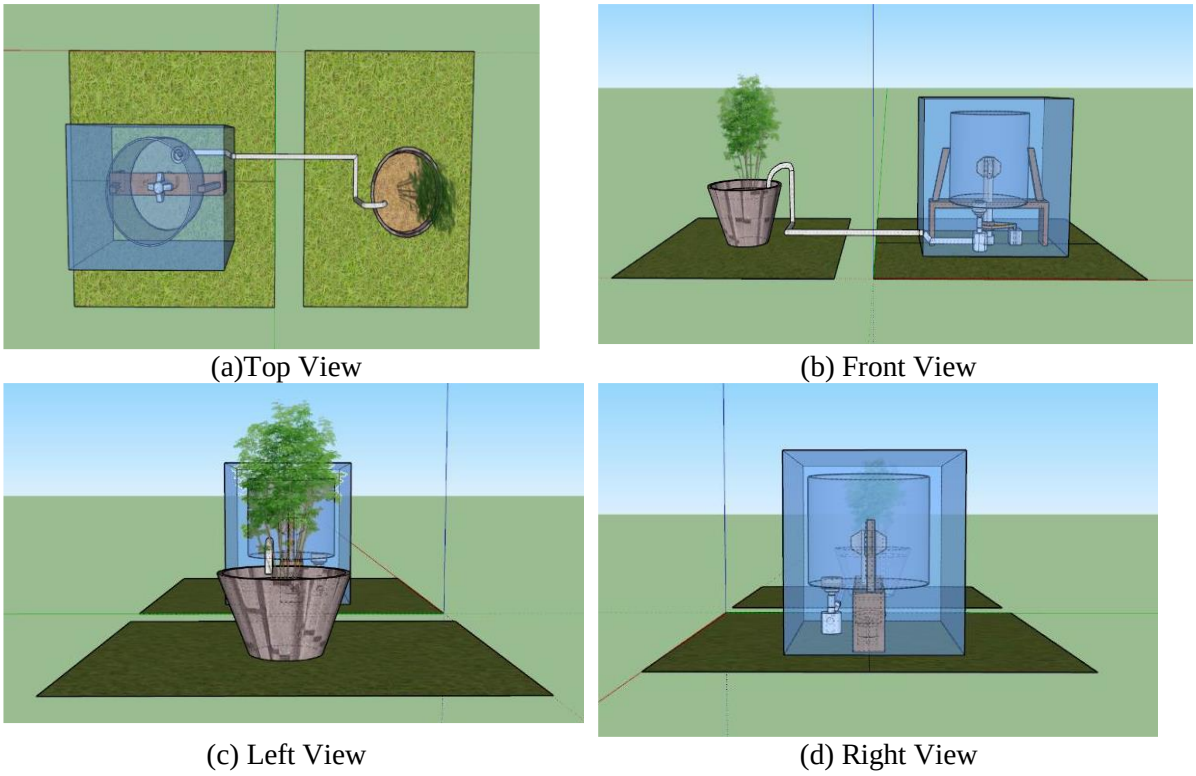
Figure 6: EC sensor

4. Results and Discussion

In this part, based on the components that have been identified will be undergoing testing in the simulation. The testing in simulation is important to know the results based on its function before being implemented into the hardware development.

4.1 Project Design

This is the initial design that has been considered to be developed for the hardware design. SketchUp software is the medium to complete the 3D design of the project. The prototype is consists of a mixer and EC sensor. The design for the mixer was inspired by a washing machine concept that had been referred [18]. There are little improvements to the mixer where the mixer motor will be helped by the DS3231 RTC and Single Channel Relay which control the starting and ending operation for the mixer. Then, from the mixer, the solution of nutrients will be supplied to the plant to be feed. So, this is all the perspective of view which consists of the side of view which is top view, front view, left view, and right view that were shown in Figure 7(a) until (d), respectively.



(a)Top View (b) Front View

(c) Left View (d) Right View

Figure 7 : View of The Project Design

4.2 Simulation Results

The simulation result from the software was discussed in this part. The circuit for the sensors related to this project was tested in the simulation software.

(a) Electricity Conductivity (EC) Sensor Circuit

The nutrients concentration can be determined by using the EC sensor. The sensor was connected to the Arduino Uno and also the value of the EC was displayed through the serial monitor on Arduino IDE. Figure 8 shows the circuit configuration of the EC sensor.

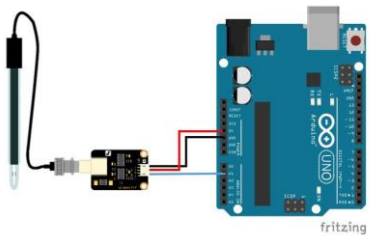


Figure 8: The circuit of EC Sensor

(b) Mixer Circuit

The mixer in this project is important where the contents of the water that were supplied to the plant need to be properly mixed. This circuit contains several components which are DC motor, 9V Battery, DS3231 Real Time Clock, Single Channel Relay, annd Arduino Uno. The mixer was operated when the motor run depends on the time that has been set. DS3231 RTC is an accurate component that can show the exact time and date. The Single Channel Delay can control the motor for the mixer based on the desired time. The motor will be turning ‘ON’ and ‘OFF’ when the relay was triggered that had been

set at a certain time. This circuit is also applicable for the water pump Figure 9 shows the circuit configuration of the mixer.

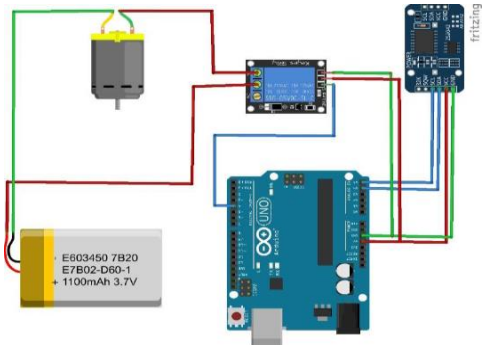


Figure 9: Circuit Configuration of the Mixer Circuit

(c) Hardware Results

The hardware for the project had been developed in part by part before being integrated into one system. Each part of the hardware is important to complete the hardware. The hardware consists of two (2) major parts which are the EC sensor and Mixer.

(i) EC Sensor Implementation and Testing

EC sensor is one of the important parts where the nutrients solution was measured to know the level of the nutrient concentration. The EC sensor coding has been compiled to the system and several testing on the solution that was tested has been conducted. The implementation of the circuit is shown in Figure 10. There are two (2) test that has been conducted which is a water test and nutrients test as shown on Figure 11 and 12, respectively. The serial monitor in the Arduino IDE is shown for water and nutrients testing in Figure 13 and Figure 14, respectively.

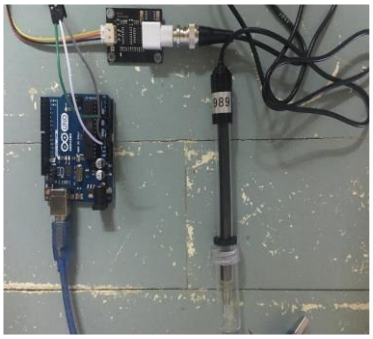


Figure 10: EC sensor circuit implementation

Figure 11: EC sensor test on nutrients

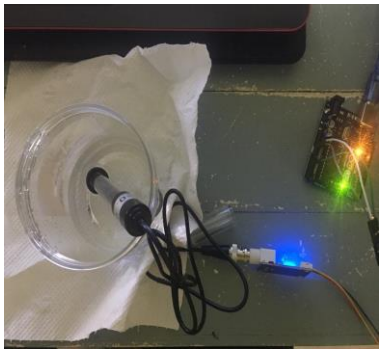


Figure 12: EC sensor test on water

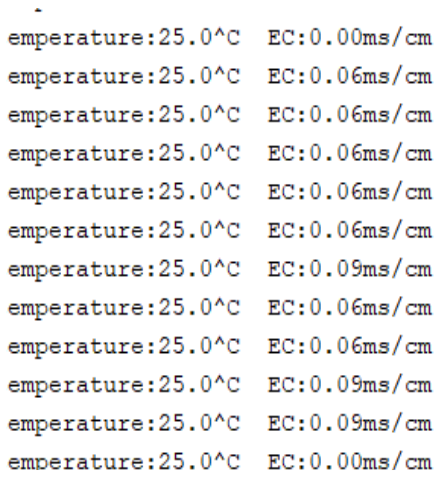


Figure 13: Serial monitor reading on water test

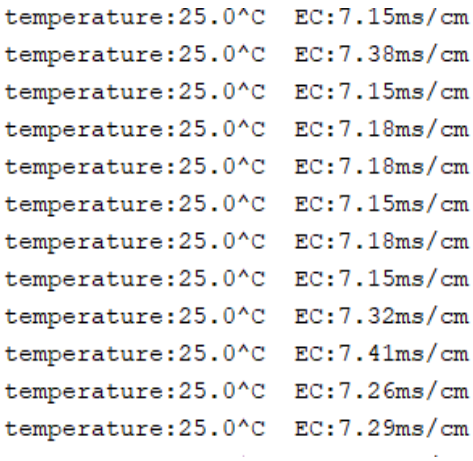


Figure 14: Serial monitor reading for nutrients

Based on the readings on the serial monitor, it shows the value of the electrical conductivity of the solution. It is really important to keep the concentration of the nutrients solution sufficient for the plant. It is a must to make sure the solution is not under or over the concentration level. Based on the Figure 14 the average of nutrients test value is 7.20ms/cm. When this value are convert to ppm is 4608ppm. The value is too high to be fed to the plant. Therefore, to get sufficient nutrients amount for the plant, water can be added to reduce the concentration. To know the amount needed to be fed to the plant, the stage of plant growth must be observed. Table 1 tabulates the nutrients needed based on the stages of plant growth [19].

Table 1: The nutrients needed based on the stages of plant growth

Stage of growth	PPM	ms/cm
Seedlings	100 – 250	0.16 – 0.39
1st half of vegging	300 – 400	0.47 – 0.63
2nd half of vegging	450 – 700	0.70 – 1.09
1st half of flowering	750 – 950	1.17 – 1.48
2nd half of flowering	1000 – 1600	1.56 – 2.50
Harvest	As close to 0 as possible	

(ii) Mixer Testing

To run the mixer, the DS3231 RTC module was used as a timer where the operating time for the system will be set at a certain time. 12V DC motor is being used to operate the shaft and the blade of the mixer. Single channel relay has been used to trigger the operation of the motor at the settings time. Figure 14 shows the circuit implementation for the timer of the mixer. Figure 15 and Figure 16 shows the mixer hardware.

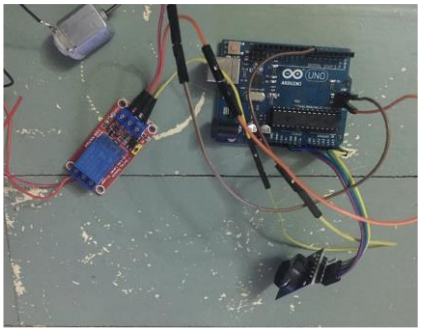


Figure 14: Circuit implementation for the timer

Figure 15: Top view of the mixer

Figure 16: Side view of the mixer

There are one setting time for the mixer operation which is timer 1. The timer can be set based on the desired time whether it is twice per day, twice per week, and more other options. As for this project, the timer was set for once per week. Table 2 tabulates the timer for the mixer operation. To activate the timer, for example Timer 1, just simply insert the command "*1*15:36:0*15:37:0#". The command can be understood with this instruction "*timer*hour:min:sec*hour:min:sec#". The mixer will be operated for one (1) minute by inserting this command.

Table 2: Timer for mixer operation

Timer	Time	Serial Monitor
1	15:36:00	MIXER ON
	15:37:00	MIXER OFF

Figure 17 until 19 shows the mixer time operation in the serial monitor.

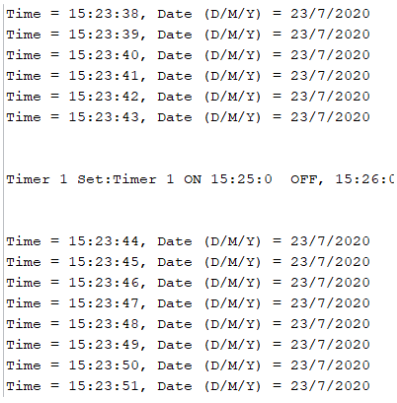


Figure 17: Timer set for the mixer in serial monitor

Figure 18: Mixer is operating in serial monitor

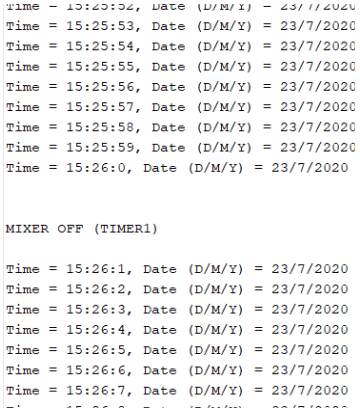


Figure 19: Mixer is off in serial monitor

5.0 Conclusion

In conclusion, the development of prototype a nutrient automation system for hydroponic is successfully developed. The objective of this project has been achieved. The nutrient automated system has been successfully developed where the mixer can properly operate. The mixer was supported by the 12V DC motor where the motor was integrated with the DS3231 RTC module. The motor was triggered for its operation by the single channel relay. Using the Arduino Uno, the coding was compiled in Arduino IDE software and the duration for the mixer operation has been set for one (1) minute. The mixer will be operated once in a week. Besides, the detection of the concentration of nutrients solution has been successfully developed. To do the detection, EC sensors are being used by using Arduino Uno. The programmed coding for the calibration has been compiled in Arduino IDE software. The calibration

was done after the mixer has mixed the water and AB fertilizer solution. The unit for the EC is ms/cm where later can be converted manually to PPM. Lastly, the mixer and the EC sensor has been successfully integrated for the mixing and calibration process.

For the recommendation, there are few improvements to be added for this project for future research and improvement. For a friendly use, the LCD can be added where it will be easier to monitor the calibration for EC, Add another sensor which is pH sensor for more accurate readings. Next, the mixer only can be used for small scale project especially hydroponic. Maybe it can be improve to a larger scale for farmers used. Lastly, high power motor for mixer can be used in consideration if the load is bigger.

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