*J. Appl. Environ. Biol. Sci.*, 7(3S)65-72, 2017



ISSN: 2090-4274
Journal of Applied Environmental and Biological Sciences
*www.textroad.com*

# Development of Automated System to Regulate Water pH with Ultrasonic Level Sensor for Indoor Fish Aquarium

**N. E. Abdullah[1], H. Hashim[1], A. D. Rosli[2], M. S. M. Yusup[1], U. R. Yussuf[1], A.F.M. Sampian[1], N.A. Khairuzzaman[1]**

[1]Faculty of Electrical Engineering, Universiti Teknologi MARA, Shah Alam, Selangor, Malaysia
[2]Faculty of Electrical Engineering, Universiti Teknologi MARA, Permatang Pauh, Pulau Pinang, Malaysia

*Received: February 21, 2017*
*Accepted: May 14, 2017*

## ABSTRACT

An essential setup for freshwater aquarium need to be considered such as temperature, water level, nitrate level, filter, aquarium lighting, pH level and others. Some of these parameters need to be regulated and maintained constantly in order to sustain the water quality in the aquarium. Practically, user need to run a test to determine whether there is a necessary to change or treat the water including other related actions to keep the aquarium safe for the aquatic species. This routine is time consuming and could interfere with user busy lifestyle as it is known as inefficient method. This paper will propose a system to treat pH level of freshwater aquarium with better system and less time consuming. Basically, this system will detect pH and water level of aquarium for treating the water automatically whenever the pH level deviates from its range. A partial of untreated water will be transferred to a treatment tank, where treatment process is being carried out and then the treated water will be supplied back to the aquarium. The level of the water in the aquarium will be detected by an ultrasonic sensor to ensure the right amount of water are being transferred to a treatment tank for avoiding any harm to the aquatic species. This system is expected to be much more convenient and have a greater efficiency in term of treating the pH level than any other conventional way in the market.

**KEYWORDS:** pH Level, Freshwater, Aquarium, Ultrasonic Sensor.

## INTRODUCTION

It is known that maintaining pH level of water is really important to freshwater fish. Usually, pH is one of the factors that frequently have been overlooked in fish care which may harm the fish and lead to fatal [1]. The pH level needs to be monitored frequently as the natural process in the tank could lead to a change in pH level [2]. In order to maintain the pH level in the aquarium, a lot of time is needed during the whole process of testing the water quality and perform the suitable action to treat it. A busy lifestyle always interferes this activity which could harm the fish even lead to fatal. PH level of 8.0 to 8.3 is consider slightly alkaline, while pH level of 4.5 to 5.0 is consider as acid [3]. In an aquarium, pH range between 6 and 8 is normally can be accepted and suitable for various types of fish. Basically, pH level in the aquarium may not always be constant where it will be high during day and low during night. This is because throughout the day the plant in the aquarium removes the carbonic acid gas and produce it during the night [4]. Therefore, a pH regulator can be used to maintain the pH level in the aquarium. Alternatively, to overcome this issue, this work focus on designing an automatic pH regulator with ultrasonic sensor that can treat the water much more efficiently and less time consuming.

## METHODOLOGY

Motive of this work is to develop an automated system for regulating the pH level for indoor aquarium. The overall view of the proposed work can be described by inexistence of human activity in checking and manually treated the pH level in the aquarium. Hence, the whole process needs to be determined prior to developing and designing of the suggested system for obtaining the knowledge and full understanding on how the operation of the system.

The flowchart in Figure 1 explain the whole process for this system. The system starts with checking the main water tank level once it is activated. As if the level is not equal to 100%, then a pump will be activated to fill the main tank. After the main tank has been filled, the system will inquire to check the pH sensor probe with pH 7 and pH 5. For example, if the pH sensor does not show a value of 7 for pH 7 solution, then a manual calibration is need to be done. After the calibration has been passed, system will initiate the standby mode.

**Corresponding Author:** N.E. Abdullah, Faculty of Electrical Engineering, Universiti Teknologi MARA, Shah Alam, Selangor, Malaysia, E-mail:noor_ezan@salam.uitm.edu.my

At this condition, the system will monitor pH and water level of main tank. If the pH level rises up more than 8.5, hence the system will alert the user to change the water. When the pH level falls below 6, treatment process will be started.

In treatment process, first the water in main tank will be removed to a treatment tank by using a pump. The removing process will stop when the level of the water in the main tank is equal or less than 50%. Then, the solution of treatment will be supplied through pump to the treatment tank. After that, one of the pump will be used to cycle the water in the treatment tank for one minute. This is to ensure the treatment solution will mix well with the water. Then, the treated water will be sent back to main tank using pump until the level of the water in the main tank is reached to 100% again. Next, pH sensor will check the pH level of the water for any changes. If the pH level is still not at the desired level, 15 minutes later, treatment process will start again. This process continues until pH level is at desired level before the system will initiate standby mode again.

**Hardware Development**

In this work, there are two sensors which are pH and ultrasonic sensor and four pumps that will be used and controlled by PIC16F877A. Both pH and ultrasonic sensors will be used to detect the pH and water level in the aquarium respectively.

**Tank Design and Component Placement**

There are two large tanks that have been used in this work and one mini tank to store treatment solution. Ultrasonic sensor, pH sensor and water transfer pump (main to treatment tank) will be placed in main tank while water transfer pump (treatment to main tank) and water cycler pump are located in the treatment tank. One more pump will be placed in treatment solution tank as solution treatment pump. Figure 2(a) and 2(b) illustrate the tank design and component placement for front view and top view respectively. Meanwhile, Figure 3(a) and 3(b) display the image of the develop aquarium system model.

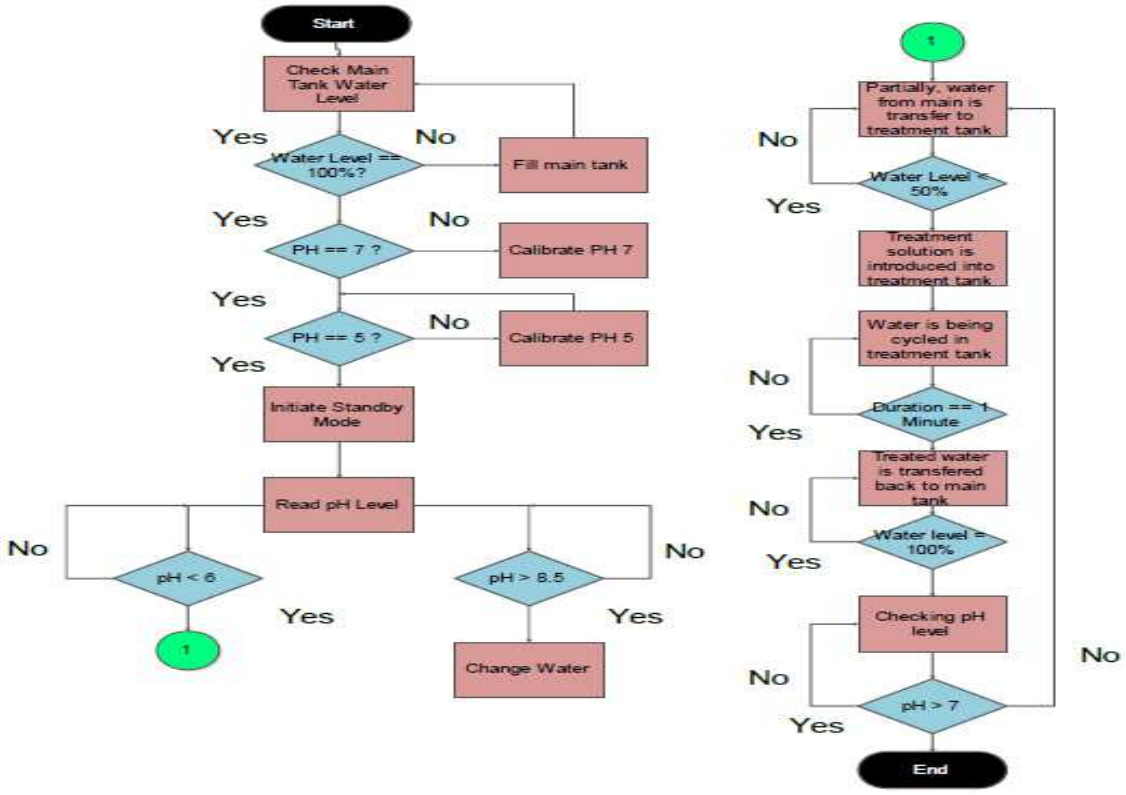


**Figure 1: Methodology flowchart**

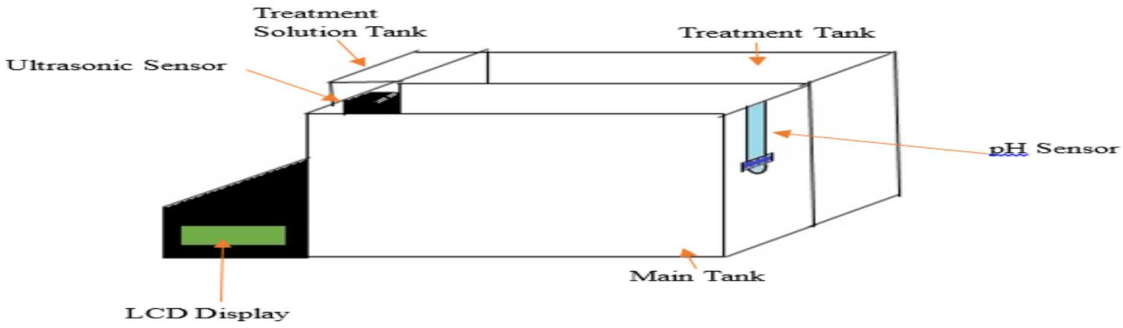


**Figure 2(a): Illustration of the tank design and component placement (front view)**

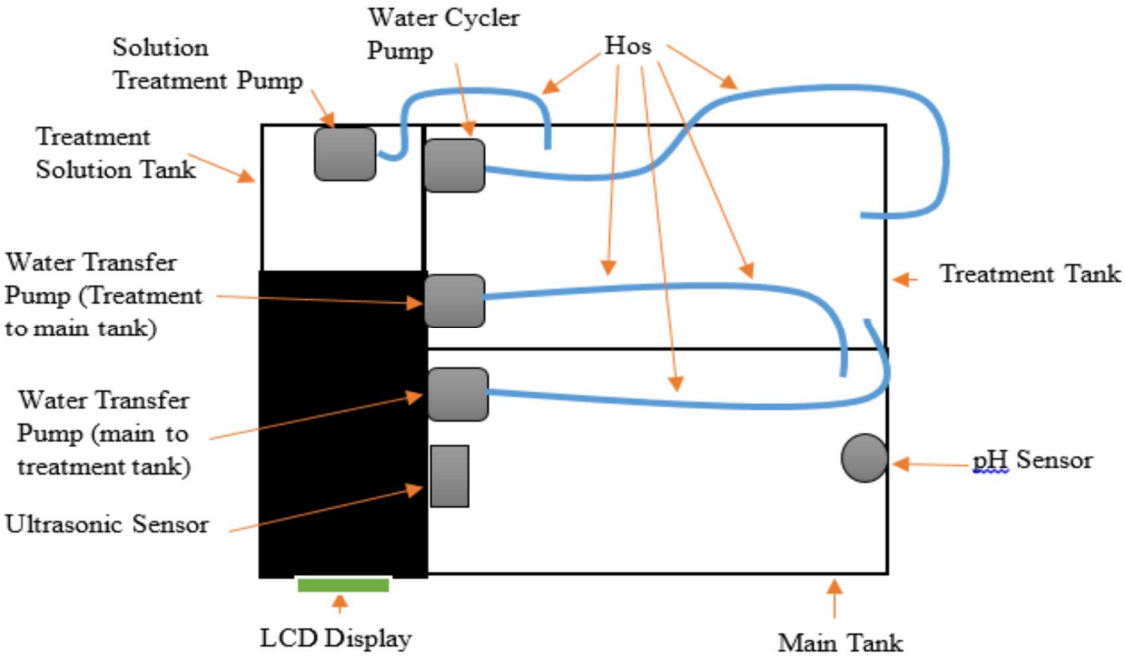


**Figure 2(b): Illustration of the tank design and component placement (top view)**

**Figure 3(a): PH aquarium system model (side view)**


**Fig. 3(b). PH aquarium system model (front view)**

**pH Sensor Principles**

The pH level is basically a measure of hydrogen ions in a solution. The hydrogen ions are an atom with a positive electrical charge. The acidity of water can be referred to pH level where it will it indicate the number of hydrogen ions in the water [5].

A voltage will be generated once the sensor being put and the value of voltage is based on the hydrogen activity in the solution. This voltage will be used for comparing with the potential of reference electrode. As the solution become more acidic, the voltage generates from the measuring electrode becomes more positive than the potential of the reference electrode and when the solution become more alkaline the voltage generate from the measuring electrode become more negative than the potential of the reference electrode. The measured potentials is a difference between these two probes [6]. This is the principles on how pH sensor work.

The basic principle of the electrode that sensitive to hydrogen ion is it has a thin glass membrane which is directly in contact with tested solution. On inside of the glass membrane, there is a silver wire, coated with silver chloride and immersed in the Hydrogen Chloride (HCL) solution called Silver Chloride (Ag/AgCl) electrode [7]. Figure 4 shows the pH probe that was used in this work.

**Figure 4: PH sensor**

**Ultrasonic Sensor Principles**

There are two operations that ultrasonic level sensor could perform is either by absorption of acoustic energy as it travels from transmitter to receiver or by changing the frequency of vibrating diaphragm face. The ultrasonic usually mounted at the top and will generate an ultrasonic pulse. Therefore, the sensor will be contactless with the water since the water in the aquarium can be corrosive when pH is acidic thus damage the sensor. The time taken for the echo to return indicated the depth of the water level [8]. The longer the time taken, the lower the water level.

The HC-SR04 ultrasonic sensor uses sonar to determine distance to an object. Its operation is not affected by sunlight or black material. The range of detection is from 2 cm to 500 cm and have a resolution of 0.3 cm. This sensor use IO trigger for at least 10 μs high level signal and automatically sends eight 40 kHz and detect whether there is a pulse signal back. If the signal is sent back through the high level, time of high output IO duration is the time from sending ultrasonic to returning. The test distance formula is given by the following equation:

Test distance [9] = (high level time x velocity of sound (340M/S)/2 (1)

**Immersible Pump**

The immersible pump use in this project has a capacity of 100-350 L/H and it works quietly with the sound level under 30 db. There are four pump use in this project and one of them is used to transfer the treatment solution and need a low pump capacity. Therefore, that pump will be given an input supply of 5 V and others are 12 V. The following Figure 5 shows the immersible pump that was used in this work.

**Figure 5: Immersible pump**

**System Circuit Block Diagram**

The block diagram is divided into three categories which are input, microcontroller and output. The system will take the input value from the pH sensor which detect the value of pH level either it is rising or fall. Then, the PIC16F877A will make a decision based on the programming to choose an action if the pH rise or fall. When the pH level rise above 8.5, the LCD will indicate the user to change the water and if the pH level falls below 6.0 the treatment process is started.

In the treatment process, the water transfer pump will transfer water from main tank to treatment tank and ultrasonic sensor will be an input to the pump either it need to continue transfer the water or stop. Then, the treatment solution pump will give a treatment solution into the treatment tank. Then, the water cycler pump will cycle the water in the treatment tank. After that, the water will be sent back into the main tank from treatment tank and once again the ultrasonic sensor will become an input for the pump to operate. Figure 6 shows the block diagram of this work.

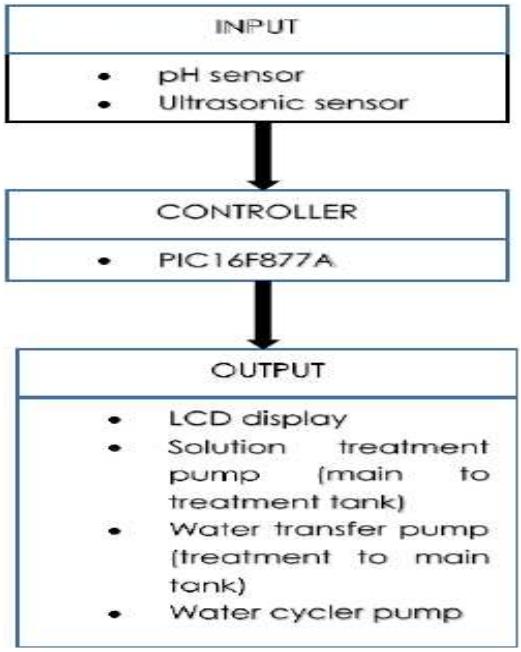


**Fig. 6. Block diagram**

**Input and Output Assignments**

In this phase, the design of the circuit need to be planned carefully to avoid any malfunctioning. Each of the input, output need to be decided prior to the process of developing the schematic diagram. Table 1 and 2 show input and output assignment respectively.

**Table 1: Input assignment**

| Inputs | Type | PIC Port |
|---|---|---|
| **pH Sensor** | Analog pH sensor | RA1 |
| **Level Sensor** | Ultrasonic | RB2,RB3 |

**Table 2: Output assignment**

| Outputs | Type | PIC Port |
|---|---|---|
| **Solution Treatment Pump** | Immersible pump, 5V | RC4 |
| **Water Transfer Pump (main to treatment tank)** | Immersible pump, 12V | RC7 |
| **Water Transfer Pump (Treatment to main tank)** | Immersible pump, 12V | RC6 |
| **Water Cycler Pump** | Immersible pump, 12V | RC5 |

## RESULTS AND DISCUSSION

### Input Part

The designed system was tested on the assigned two sensors in the input section.

### pH Sensor

These data were obtained by measuring the digital value of pH solution 4.01, 7.01 and 10.01 after being converted from analogue value. Table 3 tabulates the relationship between pH and the digital value.

**Table 3: Input assignment**

| pH | Digital Value |
|---|---|
| 4.01 | 71.20 |
| 7.01 | 112.01 |
| 10.01 | 156.00 |

The graph as shown in Figure 7 was plotted to show the relationship between the pH value and the digital value. It can be seen that there is a linear relationship between the pH and the digital value. By using a linear equation, this data can be used in the programming part for LCD to display the precise value of pH for every solution.


**Figure 7: Relationship between pH value and the respected digital value**

### Ultrasonic Sensor

A contactless level sensor is needed in order to detect the level of the water in main tank during the treatment process. In this project, a 33 x 15.2 x 20.3 cm aquarium tank is being used which can hold maximum of 9.5 litres water. An ultrasonic sensor is the most suitable one since it does not need to contact with the water to measure the water level.

As the ultrasonic sensor give an output of distance between ultrasonic sensor and the water level, the measuring parameter has being changed to percentage. The ultrasonic sensor are not able to give a good increment and decrement reading when the water is being supply in or out. This is because an echo detection problem that occurred to the ultrasonic sensor which is a common problem in using ultrasonic sensor [10]. Therefore, a delay is require during the activation of each pump since it required an input from ultrasonic sensor which are not able to give stable reading. This is to avoid damage to the pump as it will turn on and off rapidly if delay is not introduced. Table 4 shows the ultrasonic sensor readings and Figure 8 shows the distance between ultrasonic sensor and water level.

**Table 4: Ultrasonic sensor readings**

| Water Level (%) | Distance Ultrasonic and Water (cm) |
|---|---|
| 50 | 7.5 |
| 60 | 6.8 |
| 100 | 4.0 |

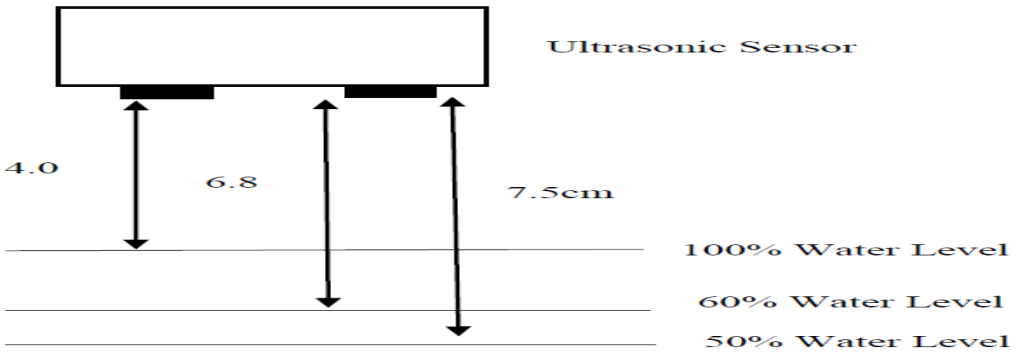


**Figure 8: Distance between ultrasonic sensor and water level**

**Output Part**

There are four pumps that are being used in this project. Three of it was using 12V supply which is water cycler pump, water transfer pump from main to tank and vice versa. Another pump was using 5V power supply which is solution treatment pump. The solution treatment pump were using the low voltage supply because it need only to pump a small amount of treatment solution. Table 5 shows the pump capacity for 5V supply and 12V supply.

**Table 5: Pump capacity**

| Supply (V) | Capacity (ml/sec) |
|---|---|
| 5 | 20 |
| 12 | 50 |

The water transfer pump for main tank to treatment tank will be activated as soon as the pH sensor detects the pH level in the water drop below 6. The pump will stop as the ultrasonic sensor detect that the water level is below 50%. Then, the treatment solution pump will turn on for one second to give the treatment solution in the treatment tank. The water cycler pump will turn on for one minute to cycle the water in the treatment tank. Lastly, the water transfer pump for treatment to the main tank is turned on and will be turned off as soon as the ultrasonic sensor detected the level of the water in the main tank is 100%. For each pump that turn on, the LED will turn on and the LCD will indicate what process the system is in.

**System Testing**

There is two condition to determine the duration of the overall process. First is the pH level of the water has rose more than 6.0 and others is the pH level are still acidic, which mean below 6.0. This happened because whenever the pH level is being checked in the last process, if the pH is more than 6.0 it only took five seconds for the system to initiate standby mode again. However, if the pH level is still below 6.0, the system will be delayed for 15 minutes to give the time for the pH sensor to detect the actual pH value of the water before going to standby mode again. Because of these two conditions, the pH level of the water in the aquarium will keep being monitor efficiently.

Water in the main tank has been tested by dropping the pH level to 6.00 and a 20ml of treatment solution was given. Table 6 shows the duration of the pH sensor to detect the change of the pH level in the main tank.

**Table 6: Duration for pH sensor to detect change of pH**

| Duration (min) | pH Level |
|---|---|
| 0 | 6.00 |
| 1 | 6.00 |
| 2 | 6.00 |
| 3 | 6.21 |
| 4 | 6..21 |
| 5 | 6.34 |
| 6 | 6.34 |
| 7 | 6.48 |
| 8 | 6.83 |
| 9 | 7.01 |
| 10 | 7.01 |
| 11 | 7.01 |
| 12 | 7.01 |
| 13 | 7.01 |
| 14 | 7.01 |
| 15 | 7.01 |

Excluding the last process of checking the pH level, the whole treatment process only took 2 minutes and 5 seconds. The system has been tested and it shows that it can increase pH level of 1.01 for every 5 litres of water.

## CONCLUSION

It can be concluded that this system is capable to work efficiently due to its ability for monitoring and treating the pH level of the water in aquarium continuously without troubling the user to check for the pH level. This will help the user to save more time since they will not have to monitor and treat the water manually, which time is consuming. Since the pH level is being maintained regularly, the aquatic species in the aquarium are expected to be healthy and will not fall sick or die cause by inappropriate pH level. Besides that, the component using in this project is the standard equipment and it is being expected the price would be reasonable and affordable.

## ACKNOWLEDGMENT

The authors would like to give their sincere gratitude to Industrial Based Instrumentation and Technology (I-BIT) Research Group members in providing facilities, support and ideas throughout the completion of this work. Lastly, not to forget special appreciation to Faculty of Electrical Engineering and Research Management Centre (RMC) UiTM for supporting this work under Research Acculturation Grant Scheme (RAGS) with code (27/2014).

## REFERENCES

1. M. Bailey and G. Sandford, 1995. The ultimate aquarium: A definitive guide to identifying and keeping freshwater and marine fishes. Smithmark Publishing.
2. M. Postlethwaite, 2010. Introduction to freshwater fishkeeping. First Edit.
3. Pynnönen, K., 1995. Effect of pH, Hardness and Maternal Pre-Exposure on the Toxicity of Cd, Cu and Zn to the Glochidial Larvae of a Freshwater Clam Anodonta Cygnea. Water Research, 29 (1): 247-254.
4. Cliff W. Emmens, 2013, Keeping and breeding aquarium fishes. Academic Press.
5. G.Skomal, 2007. Goldfish: Your happy healthy pet. Howell Book House.
6. Analog Devices, Inc., 2013. Isolated low power pH monitor with temperature compensation. Retrieved from http://www.analog.com/media/en/reference-design-documentation/reference-designs/CN0326.pdf.
7. Frederick J. Kohlmann, 2003. What is pH, and how is it measured? A technical handbook for industry. Hach Company.
8. ShioK. Singh, 2003. Industrial instrumentation and control, 2e. Tata McGraw-Hill Education.
9. Elec Freaks, 2016. Ultrasonic ranging module HC-SR04. Retrieved from http://www.micropik.com/PDF/HCSR04.pdf.
10. Andria, G., F. Attivissimo and N. Giaquinto, 2001. Digital Signal Processing Techniques for Accurate Ultrasonic Sensor Measurement. Measurement, 30(2): 105-114.