Water Flow Measurement-Based Data Acquisition Using Arduino Microcontroller and PLX-DAQ Software

Benriwati Maharmi, Bertanida Widyastomo, Fadhli Palaha
Department of Electrical Engineering, Sekolah Tinggi Teknologi Pekanbaru, Jl. Dirgantara No. 4 Arengka Raya Pekanbaru, Riau, Indonesia

ARTICLE INFO

Article history:

Received March 20, 2022
Revised April 04, 2022
Accepted April 24, 2022

Keywords:

ATMEGA328;
Data acquisition;
PLX-DAQ;
HC-SR04;
Water flow

ABSTRACT

The data acquisition for monitoring the water flows in real-time, which is available at any time, is needed for water management purposes. This paper aims to build a prototype of a water flow measurement system in an open channel of a rectangular weir box design using the American Standard Testing and Material (ASTM). This research contribution is a development of a water flow measurement, which can be used as a simulator for studies on measuring water discharge in real cases in the field. More, this instrument is based on the data logger using Arduino, which is designed at a low cost and is easy to use. This water flow equipment can be measured in real-time, so that data information can be directly obtained for analysis. The design of a data acquisition system can display water discharge data in real-time from time to time and allows data storage (data logger) as historical data that can be displayed whenever needed. The Arduino UNO ATMEGA 328 microcontroller was programmed to read the HC-SR04 water level sensor on a distance-based weir box displayed on the LCD. Monitoring and recording of data were displayed on the Parallax Data Acquisition tool (PLX-DAQ) software add-on for Microsoft Excel in real-time. The prototype was able to provide a real simulation of the water flow calculation process until the maximum design capacity of 784,384.87 liters per day. Tests on the overall performance of the water flow measurement system were carried out using flowing water media at 3 different flow conditions based on time. From the average log data of the tests carried out, the deviation of the measurement data against the ASTM calculation theory on average of 0.8 liters/minute. These results were quite good because of the 16,502 liters of water measured. The difference in the calculation results was only 1.003 liters.

This work is licensed under a Creative Commons Attribution-Share Alike 4.0

Corresponding Author:

Benriwati Maharmi, Department of Electrical Engineering, Sekolah Tinggi Teknologi Pekanbaru, Jl. Dirgantara No. 4 Arengka Raya Pekanbaru, RIAU, Indonesia
Email: benriwati@gmail.com

1. INTRODUCTION

Combining a method of measuring water flow using a standard that has been recognized in the world with electronic technology allows a measurement system to be built with many advantages. Building a structure for a water flow measurement system can be done using a rectangular weir box base [1]–[4]. A rectangular weir box is a water dam structure that has a rectangular flow gap. This structure has long been and popularly is used to measure water flow in open channels.

The availability of data for the amount of water flowing in a facility is a challenge, especially for water management facilities that use water discharge capacity as an important factor in their operations [5]–[9]. Some water management facilities that have been equipped with a water flow measurement system still use manual methods and are not real-time. It affects the accuracy of decision-making because it takes time to record and analyze data [10]–[13]. Data Acquisition System (DAQ) can be a solution to collect data information or analyze measurements using transducers, computers, and sensors that can be carried out from various input signal sources [12]–[17]. Not only analog or digital signals from various sensors, counter inputs, and frequencies, but also video input, thermo camera, GPS, CAN Bus, and input data from various sources with various types of data interfaces in real-time. Peña-Haro et al. (2021) [18] develop and combine reliable, sensitive IP cameras with high resolution, low pixel noise with powerful image rates enabling quasi-real-time measurements. They used an optical sensor to detect the water level connecting the external sensor and synchronize its measurement with the video recording. Yang et al. (2020) [19] Developed a portable particle tracking velocimetry (PIV) system to measure water surface velocity in real-time using a smartphone. Xu et 2019 [20] conducted research on a flow velocity sensing technology and examined it in a lab-scale continuous flow system under different flow velocities using the mm-sized resistance-typed sensor film (MRSF).

The process of sampling signals that measure real-world physical conditions by sensors would be converted into digital numerical values that can be manipulated by computers. Data acquisition applications are usually controlled by software programs developed using various general-purpose programming languages such as Assembly, BASIC, C++, Fortran, Java, LabVIEW, MATLAB, PLX-DAQ, etc. [19][21]–[26]. The use of LabVIEW, which is connected to Arduino, does not need to be programmed again, so it can directly command and obtain data as well as MATLAB [9][27]. However, it is more complex and expensive. The data acquisition using Arduino and connecting to Excel that already exists on each computer can easily be made by using a free and simple add-on [28] software Parallax Data Acquisition tool (PLX-DAQ) for Microsoft Excel [27]. By opening the book sheet application, Ms. Excel uses the PLX-DAQ application interface. The measurement data can be displayed and monitored directly by reading the data through a serial communication channel [29]. The data acquisition with this PLX-DAQ no longer needs to create a program. Therefore, it is easier to monitor and process data or process analysis.

There are various types of sensors used for measuring the liquid level from the previous paper [28], such as the optical type [10][30], radar type [31][32], float type [33][34], ultrasonic type [28][35]–[38], acoustic sensors [26], Temperature [39], etc. This type of ultrasonic sensor is an instrument with a small size, durable, contactless measurement, reliable, and cost-effective for distance measurement applications with simple use. This ultrasonic sensor works to measure distance based on the amount of time to send and receive ultrasonic sound waves that are reflected from the medium to be measured. The ultrasonic sensor module is commonly used in the HC-SR04 module, which is inexpensive. It can detect distances from 2 cm to 400 cm and a field of view of 15 degrees with an audio frequency of 40kHz [40].

This research focuses on a data acquisition system for measuring water flow in open channels with a Rectangular Weir Box (RWB) design using the American Standard Testing and Material (ASTM)'s standard [41]–[45]. In this paper, a simulator, the equipment prototype for studies or research on measuring water discharge, is developed as an electronic system for measurement using the HC-SR04 Ultrasonic Sensor and DHT 11 air humidity based on the Arduino UNO ATMEGA328 Microcontroller. The Arduino processes data and displaying by LCD. Then, it is monitored and displayed directly with Microsoft Excel data reading (PLX-DAQ). The digitization of data and information on water flow in the dam design can be freely monitored or even in its development can be transmitted to monitoring stations. This research contributes to the study of measuring water discharge in real cases in the field, such as dams [41] both in the industrial sector, agricultural irrigation, and other water management that requires information in the form of water discharge, which is still done manually. In this paper, they can be measured in real-time so that data information can be directly obtained for analysis. In addition, the data logger-based Arduino is an instrument that allows it to be used at a low cost and is easy to use [46].

2. METHOD

The Design Data Acquisition System (DAQ) for measuring water discharge using a Rectangular Weir Box based on an Ultrasonic Range meter using the Arduino UNO controller Atmega 328P module, which functions as the main component of data processing. The data acquisition system using the PLX-DAQ data logger add-on was designed to display water flow data in real-time and allows the data logger to be analyzed. The overall data acquisition system planning chart can be seen in Fig. 1.

The framework of a water flow measurement system and data acquisition in a rectangular weir box canal construction is illustrated in Fig. 1. It can be seen in Fig. 1 that the channel of an ultrasonic range meter sensor HC-SR04 was placed, which provided information on the distance of the water surface from the sensor. Then, the sensor position was used as a reference point of measurement. The water surface distance data from the sensor was sent to the controller (Arduino UNO ATMEGA328) [40]. The formulation and calculation based on the rectangular weir box design dimensions, the parameters needed for measuring water discharge based on ASTM standards can be calculated [41]–[45]. The design of a rectangular weir box refers to the ASTM D 5640-95, the standard guide for the selection of weirs and flumes for open channel flow measurement of water

[41][44][45] and ASTM D 5242-92, standard test method for open channel flow measurement of water with thin-plate weirs [44][45]. The entire process of calculating the measurement parameters to get the water discharge value was entirely run by the Arduino Uno processor according to the program flow that had been implanted.

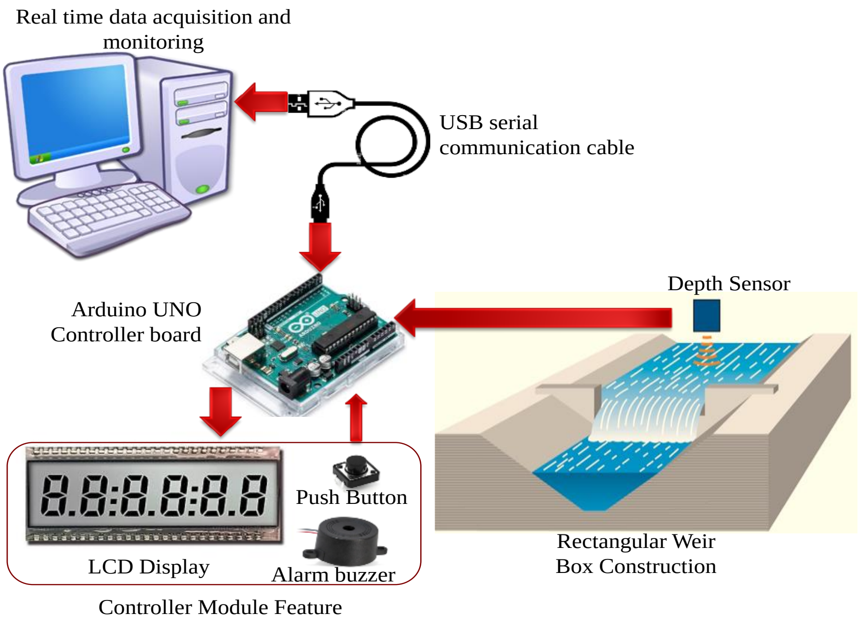


Fig. 1. Chart of the water discharge design of the data acquisition system

A PC was connected to the Arduino Uno controller as a device to display the results of water discharge measurements in real-time. Measurement results in spreadsheet/excel format can also be saved as historical data and archived. The entire data acquisition process was carried out using an add-ons data logger or data acquisition on Ms. Excel developed by Parallax (PLX-DAQ / Parallax Data Acquisition). By using these add-ons, all data that is needed by the user can be recorded in real-time. The system was also equipped with a local display in the form of an LCD, which displayed the information related to the water flow measurement system. That was including of: (1) volumetric water discharge, (2) the ambient temperature of the canal at the measurement point, and (3) the air humidity in the environment at the measurement point. A push-button input was provided to present the unit options or units of measurement for water flow to be displayed on the LCD screen. There were two options for the volumetric unit of water flow that can be displayed, namely Liters/Hours and Liters/Days. A buzzer was also added to the system to provide an option, and if the water flow limit allowed to flow in the canal becomes critical, then a set point can be determined to trigger the buzzer alarm to sound.

The computer was used for monitoring data acquisition on the water flow measurement system that was connected to the Arduino UNO ATMEGA328 microcontroller. This system used an ultrasonic-based distance sensor or the ultrasonic range meter HC-SR04 with the ability to accurately measure 2 cm to 400 cm [40]. The duration of the ultrasonic signal travel time was sent until it was received back. Therefore, it would be a time parameter to calculate the distance between the sensor and the object. The four pins contained in the ultrasonic sensor include VCC, GND, Trig, and Echo. The configuration of each of these pins was connected to the Arduino I/O pin using the scheme, namely Pin Trig, connected to pin 10 Arduino, Pin Echo, connected to pin 13 Arduino, Pin VCC, connected to a positive voltage source = 5 VDC, Pin GND, was connected to the power supply ground. The sensor component used an ultrasonic module, and the process reading value was displayed on the LCD. The 14 Input/output pins were available on the Arduino UNO ATMEGA328. It can be used for several inputs and outputs. Namely, two pins were used to connect the HC-SR04 ultrasonic sensor, one pin was used to input the DHT 11 humidity sensor, six pins were used to connect the Arduino with the display 16x2 LCD, and one pin each for Push Button input and Relay (Buzzer) output.

The ultrasonic sensor HC-SR04 was used to measure the water level passing through the weir box by determining the height of the canal and the water level from the measurement point (sensor). The depth of the measuring channel minus the distance between the ultrasonic sensor and the water surface would be produced as the water depth in the measurement canal.

2.1. Data Acquisition System Design

The design of the data acquisition system was aimed to be able to display water discharge data in real-time from time to time and allow data storage (data logger) as historical data that can be displayed at any time needed [18][19]. The design used the PLX-DAQ data logger add-on. All data from the plant or required observation points can be recorded in real-time and stored for analysis [27][29]. The flowchart of the data acquisition system is depicted in Fig. 2.

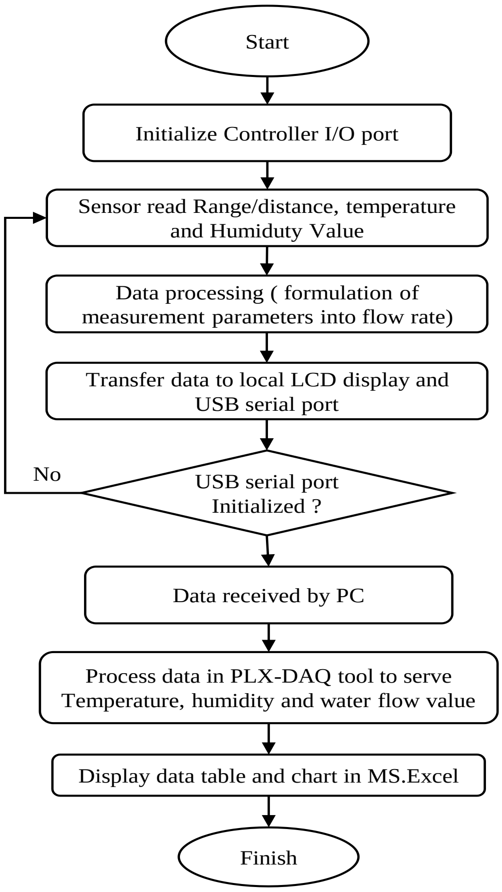


Fig. 2. Data acquisition flowchart

According to the flow chart in Fig. 2, the data acquisition process started from the initialization of the port connected to the sensor. The values read by each sensor were then digitized to produce measurement parameters that were ready to be processed. These measurement parameters were formulated to calculate the flow of water flowing in the rectangular weir box canal.

Formulation data in the form of water discharge values in real-time and continuously was displayed on the LCD display and sent via a USB serial port on a PC. The Ms. Application (Excel) that had been planted with the PLX-DAQ add-on program had been run on a PC to synchronize communication and transfer data from the Arduino Uno controller via the USB serial port. The Ms. Excel spreadsheet then displayed the real-time water flow measurement data along with process parameters such as temperature and humidity.

Based on the ease of using PLX-DAQ Excel data acquisition [27], which was connected to the ATMega 328 Microcontroller, which has a RISC (Reduced Instruction Set Computer) architecture that has a faster data execution process than a microcontroller with a CISC (Completed Instruction Set Computer) architecture. Other features possessed by ATMEGA 328 were having an EEPROM (Electrically Erasable Programmable Read-Only Memory) with a capacity of 1KB as a place for semi-permanent data storage [39][40]. The EEPROM can still store data even though the power supply is off. The capacity of SRAM (Static Random Access Memory) was 2KB, equipped with 14 digital I/O pins, 6 of the PWM (Pulse Width Modulation) output [38]. The data acquisition process requires configuration on the PLX-DAQ menu, especially to equalize some of the most important communication parameters, namely the serial communication channel (COM3) and data transfer speed [27]. In this case, the value of 9600 bps was used. The PLX-DAQ menu can be seen in Fig. 3.

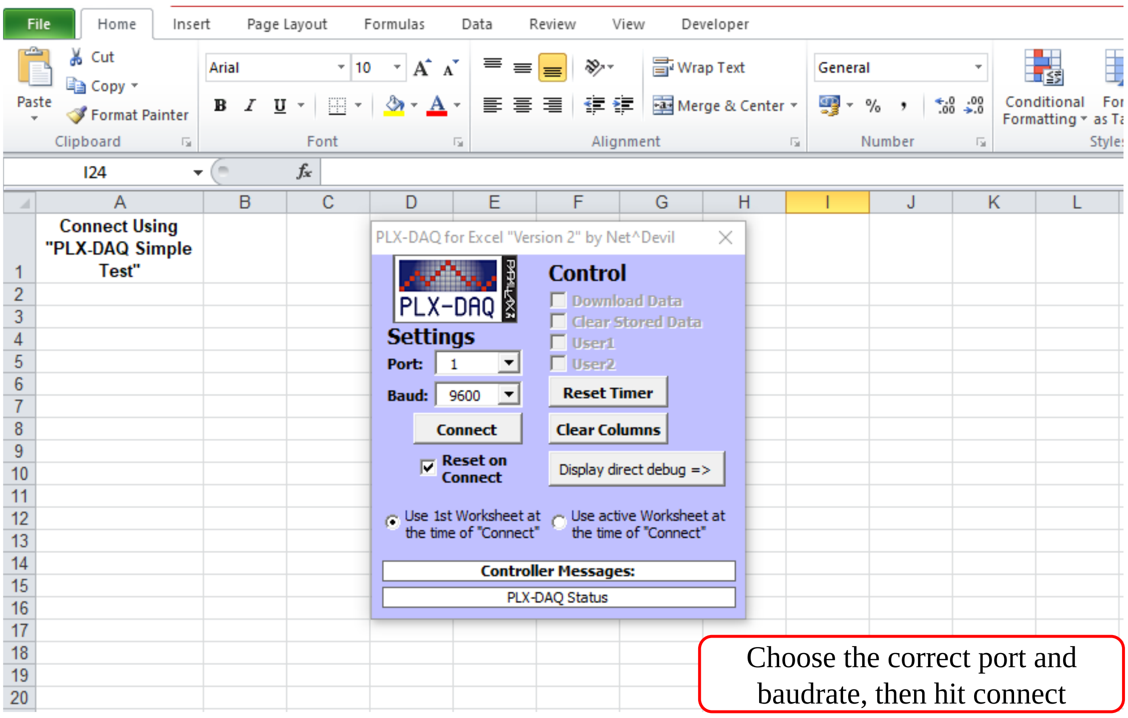


Fig. 3. The configuration of the add-on PLX-DAQ

2.2. Rectangular Weir Box

The weir box was basically a dam built open with a dam structure made perpendicular to the axis of the open channel to measure the flow rate of water by making water overflow through the structure by measuring the depth of the water at the base. The construction of a weir box structure was depicted in Fig. 4 [44][45].

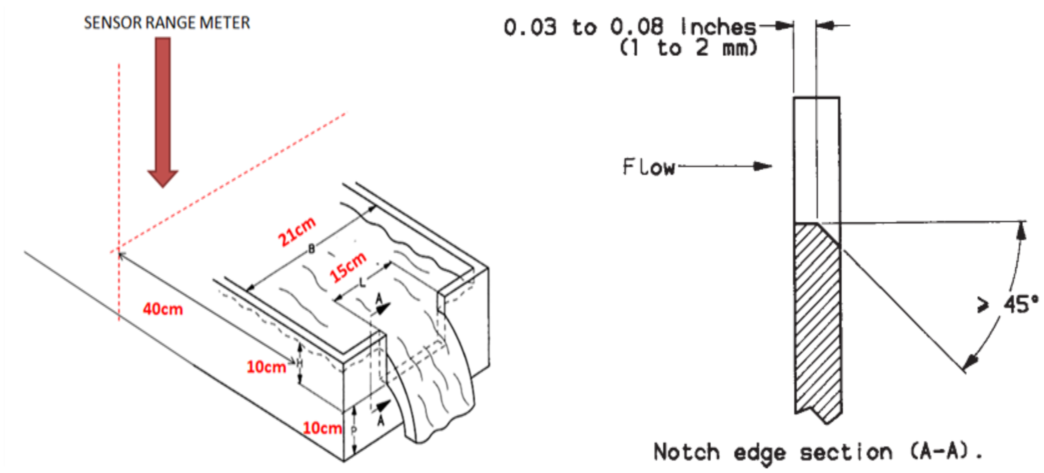


Fig. 4. Weir rectangular design scheme

The rectangular weir prototype was built as a channel with dimensions according to Table 1. It can be seen in Table 1 that the minimum sensor distance from the lip of the weir slit (upstream measurement point) was 40 cm, the channel depth of 20 cm, the width of 21 cm, and the straight upstream measurement distance of 300 cm. The volumetric flow rate calculation was obtained from the reference formula in Equation (1) [41]–[45].

$$Q = \frac{2}{3}(2g)^{\frac{1}{2}}\, Ce.Le.He^{\frac{3}{2}} \tag{1}$$

Where the volumetric rate of flow (Q), g=[32.17 Ft/s] was the flow rate that was affected by the acceleration of gravity, discharge coefficient Ce= 0.602+0.075 (H/P), the calculated crest length adjustment (Le), and calculate effective head (He).

Table 1. Rectangular weir design dimensions

Parameter	Dimensions		
	Description	**cm**	**Feet (ft)**
H	Maximum measured head	10	0.33
P	Distance from the bottom of the canal to the lip of the measuring gap	10	0.33
L	Crest length adjustment	15	0.49
B	Channel width	21	0.70

This measurement system was designed as a prototype/simulator of a water flow measurement system, namely in an open channel with a rectangular weir design using an ultrasonic range meter sensor. The design used a rectangular weir mounted on an open channel tub made of plastic or PVC boards according to the dimensions of the channel in the design. Other measuring devices used to assist in the design were a measuring ruler and a scaled water reservoir or measuring bucket. In order to match the range meter and weir unit, a ruler was placed on the channel to ensure the range meter reads the appropriate value. The flow out of this prototype would be accommodated and then measured using a water volume meter or a scale reservoir.

Table 2 shows the design of the range of water discharge values that can be flowed by the rectangular weir design. The experimental results were written in the form of a table of test results, and the difference between the measurement results and the theoretical measurement results was calculated to determine the amount of tool error.

Table 2. The water discharge range is based on the weir box design

The height of water level from the weir lip (H)		Water flow debit		
cm	**Inchi**	**ft^3/second**	**L/second**	**L/day**
3.00	1.18	0.05	1.54	132.997
3.50	1.38	0.07	1.93	166.534
4.00	1.57	0.08	2.34	202.495
4.50	1.77	0.10	2.79	240.726
5.00	1.97	0.11	3.25	281.100
5.50	2.17	0.13	3.74	323.508
6.00	2.36	0.15	4.26	367.857
6.50	2.56	0.17	4.79	414.066
7.00	2.76	0.19	5.35	462.063
7.50	2.95	0.21	5.92	511.783
8.00	3.15	0.23	6.52	563.168
8.50	3.35	0.25	7.13	616.167
9.00	3.54	0.27	7.76	670.731
9.50	3.74	0.30	8.41	726.817
10.00	3.94	0.32	9.08	784.385

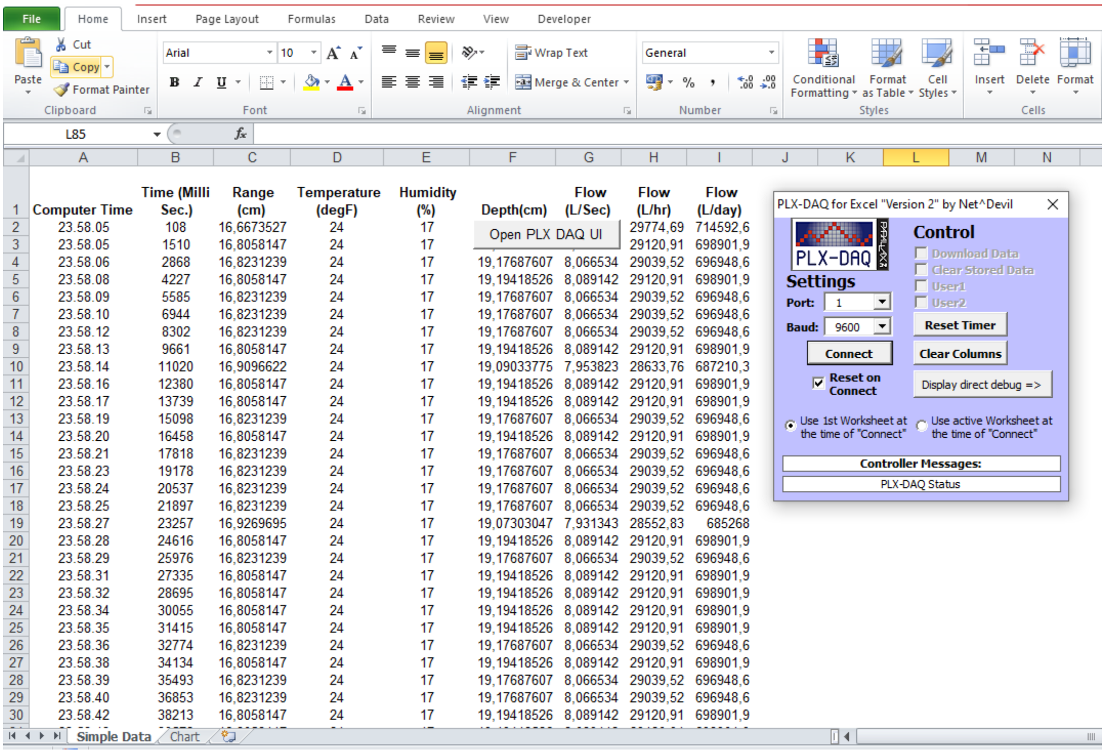
3. RESULTS AND DISCUSSION

3.1. Data Acquisition

Based on the results of the PLX-DAQ Data acquisition test, it was certain that the data acquisition application could continuously communicate with the COM3 serial channel with configured parameters. This PLX-DAQ application basically projects all of the serial data in a program display, which was more commonly used for data processing, namely Ms. Excel. The data transfer rate has used the value of 9600 bps.

All parameters were set in the PLX-DAQ menu application and the system running. The data acquisition system displayed the real-time data that appeared on the Ms. Sheet-Excel. The real-time data display of this data acquisition process is shown in Fig. 5. Fig. 5 displayed the tabulation of the data acquisition process from MS. Excel that had been planted with the PLX-DAQ add-on application as an embedded add-ons data logger developed by Parallax. Since the Arduino controller was connected via USB serial port communication on the monitoring PC, the data defined in the program listing would be displayed in a Ms. Excel spreadsheet. Calling the process parameters was done by initializing the port and data transfer speed (baud rate) by adding the following command to the Arduino program listing.

```
Serial.begin(9600);
Serial.println("CLEARDATA");
Serial.println("LABEL,Computer Time,Time (Milli Sec.), Range (cm), Temperature (degC), Humidity (%), Depth(cm), Flow (L/Sec), Flow (L/hr), Flow(L/day)");
```



	Computer Time	Time (Milli Sec.)	Range (cm)	Temperature (degF)	Humidity (%)	Depth(cm)	Flow (L/Sec)	Flow (L/hr)	Flow (L/day)
2	23.58.05	108	16,6673527	24	17			29774,69	714592,6
3	23.58.05	1510	16,8058147	24	17			29120,91	698901,9
4	23.58.06	2868	16,8231239	24	17	19,17687607	8,066534	29039,52	696948,6
5	23.58.08	4227	16,8058147	24	17	19,19418526	8,089142	29120,91	698901,9
6	23.58.09	5585	16,8231239	24	17	19,17687607	8,066534	29039,52	696948,6
7	23.58.10	6944	16,8231239	24	17	19,17687607	8,066534	29039,52	696948,6
8	23.58.12	8302	16,8231239	24	17	19,17687607	8,066534	29039,52	696948,6
9	23.58.13	9661	16,8058147	24	17	19,19418526	8,089142	29120,91	698901,9
10	23.58.14	11020	16,9096622	24	17	19,09033775	7,953823	28633,76	687210,3
11	23.58.16	12380	16,8058147	24	17	19,19418526	8,089142	29120,91	698901,9
12	23.58.17	13739	16,8058147	24	17	19,19418526	8,089142	29120,91	698901,9
13	23.58.19	15098	16,8231239	24	17	19,17687607	8,066534	29039,52	696948,6
14	23.58.20	16458	16,8058147	24	17	19,19418526	8,089142	29120,91	698901,9
15	23.58.21	17818	16,8231239	24	17	19,17687607	8,066534	29039,52	696948,6
16	23.58.23	19178	16,8231239	24	17	19,17687607	8,066534	29039,52	696948,6
17	23.58.24	20537	16,8231239	24	17	19,17687607	8,066534	29039,52	696948,6
18	23.58.25	21897	16,8231239	24	17	19,17687607	8,066534	29039,52	696948,6
19	23.58.27	23257	16,9269695	24	17	19,07303047	7,931343	28552,83	685268
20	23.58.28	24616	16,8058147	24	17	19,19418526	8,089142	29120,91	698901,9
21	23.58.29	25976	16,8231239	24	17	19,17687607	8,066534	29039,52	696948,6
22	23.58.31	27335	16,8058147	24	17	19,19418526	8,089142	29120,91	698901,9
23	23.58.32	28695	16,8058147	24	17	19,19418526	8,089142	29120,91	698901,9
24	23.58.34	30055	16,8058147	24	17	19,19418526	8,089142	29120,91	698901,9
25	23.58.35	31415	16,8058147	24	17	19,19418526	8,089142	29120,91	698901,9
26	23.58.36	32774	16,8231239	24	17	19,17687607	8,066534	29039,52	696948,6
27	23.58.38	34134	16,8058147	24	17	19,19418526	8,089142	29120,91	698901,9
28	23.58.39	35493	16,8231239	24	17	19,17687607	8,066534	29039,52	696948,6
29	23.58.40	36853	16,8231239	24	17	19,17687607	8,066534	29039,52	696948,6
30	23.58.42	38213	16,8058147	24	17	19,19418526	8,089142	29120,91	698901,9

Fig. 5. Display of data acquisition on MS. Excel

The table in the Ms. Excel application can display all the parameters defined in the program, listing them in columns and rows with a timestamp or data sampling every second. The data can be added dynamically in the table columns as long as the PC connection and controller are connected. The presentation of data in the form of a graph had been moved continuously following changes in process data that were shown in Fig. 6. The data was always changed in real-time. So, it was easier to observe the process parameters.

By getting the data process in tabulation, dynamic and real-time data changes were allowed to be displayed in a chart or graph. It can be seen in Fig. 6, a run-chart of the measurement parameters that can be observed at any time and can be archived or stored in the form of a historian. Parameter visualization using the run-chart was very helpful in analyzing the flow process in the channel. The trend of the flow would be seen by looking at the trending graph. It was very helpful when baseline data was needed to make decisions regarding the flow process itself.

3.2. Water Discharge Measurement

The calculation of water discharge using a rectangular weir was obtained the parameter of values length to channel ratio = L/B = 15/21 = 0.70. The head-to-crest height ratio H/P = 10/10 = 1, crest length adjustment L was 0.013 Ft. Then, Le can be calculated by adding up L and L, which was 0.49 + 0.013 feet = 0.503 feet, H=0.003 Ft (Valid for water media at a temperature of 4-30 0C), He=0.33+ 0.003=0.333 Feet. Then, the maximum water discharge can be measured from the rectangular weir design with equation (1). The water discharge was 784,384.87 Liters/day.

The test was carried out to obtain data from the measurement of water discharge to be compared with the theory used [42]–[45], which was based on the ASTM standard. The standard ASTM is the standard used for the standard test method for open channel flow measurement of water with thin-plate weirs [44][45]. The function Q (flow rate) was generated by the variable height of the water surface from the edge of the dam lip when water flows through the rectangular weir box. Because the measurement system was already connected to the data acquisition application, the recording of the calculation results was taken from the table (sheet) of

MS Excel, which was connected to the Arduino serial data board via PLX-DAQ. The test process is shown in Fig. 7.

Fig. 6. The real-time graph displays of data acquisition on Ms. Excel

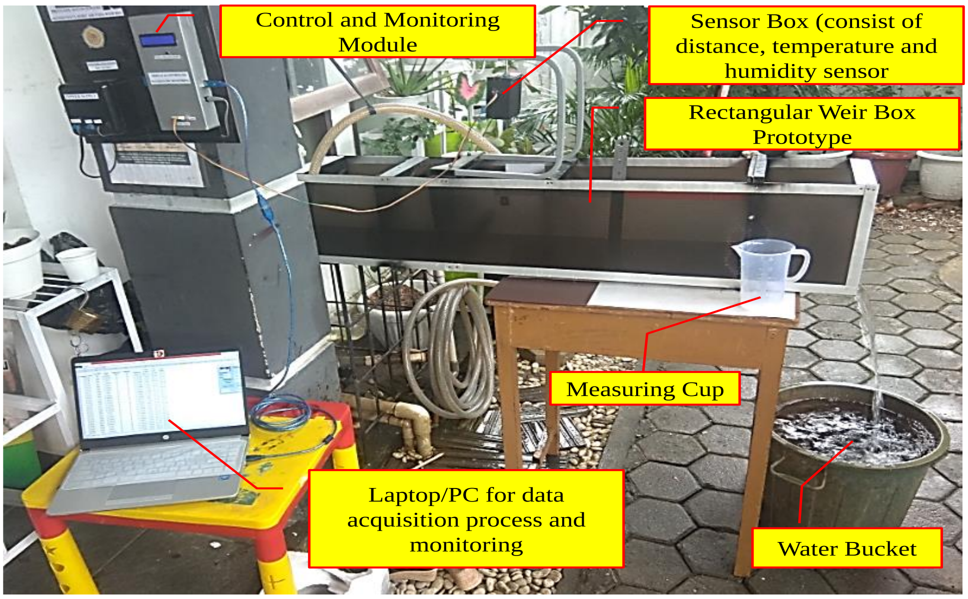


Fig. 7. The prototype of the overall water flow measurement

The test was carried out by flowing water with various discharges into the canal prototype. The water was used water flows from a home consumption water pump, so the discharge was very limited to reach the entire prototype range. Each volume of water sample was taken within 1 minute, then the amount of water that was accommodated in the reservoir was measured manually using a measuring cup.

Table 3 presents the sampling data alternately for different water discharges for 1 minute. Data snippets were taken in a time range of 1.36 seconds. Then, in 1 minute, 44 data appeared. Samples of test data were taken for 3 different flow conditions. The log data from each sampling would be averaged so that the measurement capacity was obtained in 1 minute. The result of testing with sampling data that has been averaged to be compared with measurements of water samples was accommodated in vessels using measuring cups depicted in Table 3.

Deviation (ΔQ) or an error was obtained from the difference in the data from the tool measurement results (Qm) minus the data from the theoretical calculations (Qt) in Equation 2.

$$\Delta Q = Qm - Qt \tag{2}$$

Therefore, the % error can be defined as the % of tool measurement error (Qm) compared to the theoretical calculation value (Qt) in Equation 3.

$$\%error = \frac{\Delta Q}{Qt} \times 100\% \tag{3}$$

Table 3. Results of testing water capacity (water discharge)

Water Depth (cm)	The water height from the dam lip (cm)	Water flow debit (Liter / minute)		Deviation (ΔQ=Qm-Qt) L/min	%error =ΔQ/Qt ×100%
		Theoretical ASTM (Qt)	Measurement Sample Average (Qm)		
10.21	0.21	2.875	3.509	0.634	22.05%
10.71	0.71	12.753	13.532	0.779	6.11%
10.88	0.88	16.502	17.505	1.003	6.08%

From Table 3, it can be seen that for testing with flows approaching the dam threshold, with a water level of only 0.21cm above the dam. It had the consequence of low accuracy. The water surface stability factor in this test was very large. The method used hoses with high flow rates and pressures contributes to a large enough error. However, when the hose valve was opened large enough for the second and third samples, the relative error value dropped.

Table 3 presents test data on three flow samples with water depths measured by sensors of 10.21 cm, 10.71 cm, and 10.88 cm, respectively. The factor of water sources that have adequate water discharge with the capacity of the dam prototype was an obstacle to getting more measurement samples.

The test results data were compared with theoretical calculations (ASTM) in Equation (1) [41]–[45] to test the accuracy of the dam construction design. The more precise the design and construction of the dam in accordance with the ASTM-based rules, the final result of the water discharge measurement can approach the actual value. Therefore, the error that may depend on the precision and accuracy of the sensor measuring the water level.

Based on the comparison of test results in Fig. 8, the measurement experienced a shift in value compared to the theoretical calculation of 0.8 Liters per minute. But, in general, the deviation looked even for several test points. From this, it was possible to provide a correction factor to the system. Therefore, the measurement results approached the theoretical value.

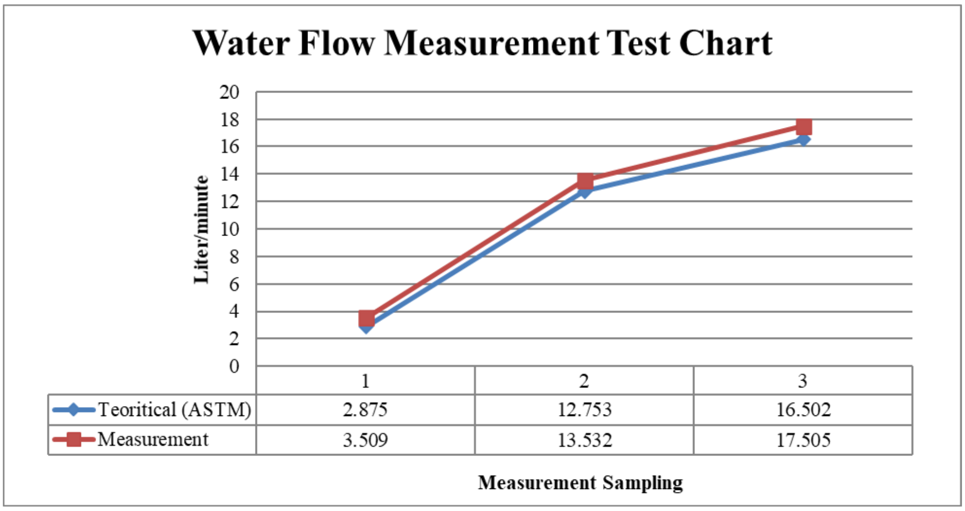


Fig. 8. Test result graph

The difference in the measurement results or deviation from the test is shown in Fig. 9. From the graph, there was a trend of increasing deviation for each increase in measurement capacity. The increase in deviation tends to be linear so that improvements to the measurement value other than adding a correction factor can be made by calibrating the proximity sensor to match the theory in the water flow measurement formula (ASTM) [41]–[45].

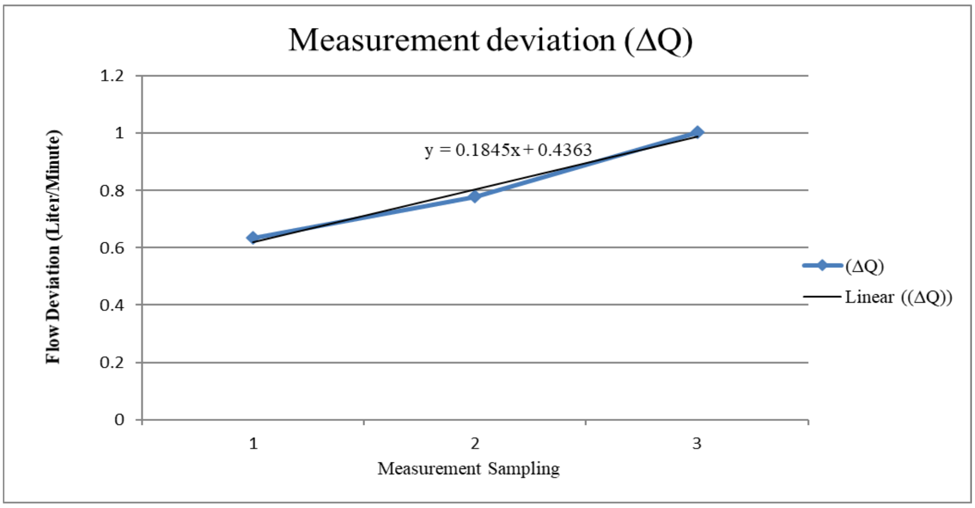


Fig. 9. The test result of the deviation graph

4. CONCLUSION

In this study, the results of Monitoring Data Acquisition measuring water discharge in real-time using a rectangular weir box that refers to the ASTM standard have been successfully created and displayed in Ms. Excel. The prototype was able to provide a real simulation of the water discharge calculation process until the maximum design capacity was 784384.87 liters per day. Tests on the overall performance of the water flow measurement system were carried out using flowing water media at 3 different flow conditions based on time. From the average test log data, the deviation of the measurement data from the ASTM calculation theory was an average of 0.8 liters/minute. These results were quite good because of the 16,502 liters of water measured. The difference in the calculation result was only 1.003 liters. The deviation in some samples of water flow measurement was close to linear, making it possible to enter a correction factor value to improve the overall measurement results.

REFERENCES

[1] S. Li, J. Yang, and A. Ansell, "Discharge prediction for rectangular sharp-crested weirs by machine learning techniques," *Flow Meas. Instrum.*, vol. 79, p. 101931, 2021, https://doi.org/10.1016/j.flowmeasinst.2021.101931.

[2] H. Imanian, A. Mohammadian, and P. Hoshyar, "Experimental and numerical study of flow over a broad-crested weir under different hydraulic head ratios," *Flow Meas. Instrum.*, vol. 80, no. May, p. 102004, 2021, https://doi.org/10.1016/j.flowmeasinst.2021.102004.

[3] E. Jahanpanah, P. Khosravinia, H. Sanikhani, and O. Kisi, "Estimation of discharge with free overfall in rectangular channel using artificial intelligence models," *Flow Meas. Instrum.*, vol. 67, pp. 118–130, 2019, https://doi.org/10.1016/j.flowmeasinst.2019.04.005.

[4] A. Shariq, A. Hussain, and M. A. Ansari, "Lateral flow through the sharp crested side rectangular weirs in open channels," *Flow Meas. Instrum.*, vol. 59, pp. 8–17, 2018, https://doi.org/10.1016/j.flowmeasinst.2017.11.007.

[5] S. K. Jaiswal, S. Yadav, and R. Agarwal, "Design and development of a novel water flow measurement system," *Measurement*, vol. 105, pp. 120–129, 2017, https://doi.org/10.1016/j.measurement.2017.04.018.

[6] J. Ji, J. Zheng, G. Chen, X. Wu, N. Zhang, Y. Fang, and L. Cheng, "Numerical and experimental studies on the influences of flow field on the measurement accuracy of ultrasonic water meters," *Meas. Sensors*, vol. 18, p. 100137, 2021, https://doi.org/10.1016/j.measen.2021.100137.

[7] K. Kawakita, N. M. Taira, and V. Ruiz, "Pitometry as a validation tool for water flow measurement in large diameter pipelines," *Flow Meas. Instrum.*, vol. 79, p. 101895, 2021, https://doi.org/10.1016/j.flowmeasinst.2021.101895.

[8] F. C. de Almeida, E. C. de Oliveira, and C. R. H. Barbosa, "Design of experiments to analyze the influence of water content and meter factor on the uncertainty of oil flow measurement with ultrasonic meters," *Flow Meas. Instrum.*, vol. 70, p. 101627, 2019, https://doi.org/10.1016/j.flowmeasinst.2019.101627.

[9] H. Hao and H. L. Zhang, "Design of flow measurement system based on LabVIEW," in *IOP Conference Series: Materials Science and Engineering*, 2020, vol. 789, no. 1, p. 12027, https://doi.org/10.1088/1757-899X/789/1/012027.

[10] K. V Santhosh, B. Joy, and S. Rao, "Design of an instrument for liquid level measurement and concentration analysis

using multisensor data fusion," *J. Sensors*, vol. 2020, 2020, https://doi.org/10.1155/2020/4259509.
[11] J.-Y. Kim, J.-H. Lee, S.-E. Bae, S. Paek, S. H. Kim, T.-J. Kim, and T.-H. Park, "Automated high-temperature liquid level measurement system using a dynamic tube pressure technique," *J. Ind. Eng. Chem.*, vol. 49, pp. 30–35, 2017, https://doi.org/10.1016/j.jiec.2016.10.041.
[12] R. Paul and A. Sengupta, "Design and application of discrete wavelet packet transform based multiresolution controller for liquid level system," *Isa Trans.*, vol. 71, pp. 585–598, 2017, https://doi.org/10.1016/j.isatra.2017.07.030.
[13] D. Biswas, K. Kumar, V. Rohilla, G. S. Kathait, P. Thapliyal, A. S. Bahuguna, Y. Pundir, and V. P. Tamta, "Microcontroller based data acquisition system using error reduction technique," *Int. J. Eng. Sci. Technol.*, vol. 11, no. 3, pp. 40–48, 2019, https://doi.org/10.4314/ijest.v11i3.5.
[14] J. Li, S. Bao, and S. Burian, "Real-time data assimilation potential to connect micro-smart water test bed and hydraulic model," *H2Open J.*, vol. 2, no. 1, pp. 71–82, 2019, https://doi.org/10.2166/h2oj.2019.006.
[15] B. F. de Moura, M. F. Martins, F. H. S. Palma, W. B. da Silva, J. A. Cabello, and R. Ramos, "Design of a low-cost acquisition system to reconstruct images through electrical resistance tomography," *IEEE Lat. Am. Trans.*, vol. 18, no. 09, pp. 1592–1598, 2020, https://doi.org/10.1109/TLA.2020.9381801.
[16] L. Ashok and B. R. Murthy, "Liquid Level Monitoring and Flow based Liquid Distribution System using PLC and SCADA," *Environ. Sci.*, vol. 8, no. 12, pp. 118–126, 2019, https://doi.org/10.17577/IJERTV8IS120048.
[17] L. Chen, Y. Kim, and Y. Bae, "Long range displacement measurements systems using guided wave," *Int. J. Fuzzy Log. Intell. Syst.*, vol. 17, no. 3, pp. 154–161, 2017, https://doi.org/10.5391/IJFIS.2017.17.3.154.
[18] S. Peña-Haro, M. Carrel, B. Lüthi, I. Hansen, and R. Lukes, "Robust Image-Based Streamflow Measurements for Real-Time Continuous Monitoring," *Front. Water*, p. 175, 2021, https://doi.org/10.3389/frwa.2021.766918.
[19] T. Yang, Z. Liu, Y. Chen, and Y. Yu, "Real-time, inexpensive, and portable measurement of water surface velocity through smartphone," *Water (Switzerland)*, vol. 12, no. 12, pp. 1–13, 2020, https://doi.org/10.3390/w12123358.
[20] Z. Xu, Y. Fan, T. Wang, Y. Huang, F. MahmoodPoor Dehkordy, Z. Dai, L. Xia, Q. Dong, A. Bagtzoglou, J. McCutcheon, Y. Lei, and B. Li, "Towards high resolution monitoring of water flow velocity using flat flexible thin mm-sized resistance-typed sensor film (MRSF)," *Water Res. X*, vol. 4, p. 100028, 2019, https://doi.org/10.1016/j.wroa.2019.100028.
[21] O. Penttinen, M. Ulvestrӧm, K. Karlsson, V. Andersson, H. Andersson, J. Pettersson, and O. Büker, "Towards flow measurement with passive accelerometers," *Flow Meas. Instrum.*, vol. 80, p. 101992, 2021, https://doi.org/10.1016/j.flowmeasinst.2021.101992.
[22] T. H. L. Nguyen and S. Park, "Multi-angle liquid flow measurement using ultrasonic linear array transducer," *Sensors*, vol. 20, no. 2, p. 388, 2020, https://doi.org/10.3390/s20020388.
[23] A. D. Zand, K. Khalili-Damghani, and S. Raissi, "Designing an intelligent control philosophy in reservoirs of water transfer networks in supervisory control and data acquisition system stations," *Int. J. Autom. Comput.*, vol. 18, no. 5, pp. 694–717, 2021, https://doi.org/10.1007/s11633-021-1284-1.
[24] K. Abbas, L. Haijian, Y. Ting, Z. Shiliang, and M. Ali Shahzad, "Development of Wire Mesh Sensor to Study Two Phase Flow and its Comparison With High Speed Camera," in *International Conference on Nuclear Engineering*, 2017, vol. 57847, p. V006T08A055, https://doi.org/10.1115/ICONE25-66760.
[25] K. J. Kumaresh, P. D. Raj, and M. Sridharan, "Design of thin film capacitive sensor for flow measurement," *Mater. Today Proc.*, vol. 3, no. 6, pp. 1517–1524, 2016, https://doi.org/10.1016/j.matpr.2016.04.036.
[26] X. Zhang, D. Maddipatla, B. B. Narakathu, B. J. Bazuin, and M. Z. Atashbar, "Development of a Novel Wireless Multi-Channel Stethograph System for Monitoring Cardiovascular and Cardiopulmonary Diseases," *IEEE Access*, vol. 9, pp. 128951–128964, 2021, https://doi.org/10.1109/ACCESS.2021.3111778.
[27] D. Nichols, "Arduino-Based Data Acquisition into Excel, LabVIEW, and MATLAB," *Phys. Teach.*, vol. 55, no. 4, pp. 226–227, 2017, https://doi.org/10.1119/1.4978720.
[28] A. K. Sahoo and S. K. Udgata, "A Novel ANN-Based Adaptive Ultrasonic Measurement System for Accurate Water Level Monitoring," *IEEE Trans. Instrum. Meas.*, vol. 69, no. 6, pp. 3359–3369, 2020, https://doi.org/10.1109/TIM.2019.2939932.
[29] A. El Hammoumi, S. Motahhir, A. Chalh, A. El Ghzizal, and A. Derouich, "Low-cost virtual instrumentation of PV panel characteristics using Excel and Arduino in comparison with traditional instrumentation," *Renewables Wind. Water, Sol.*, vol. 5, no. 1, pp. 1–16, 2018, https://doi.org/10.1186/s40807-018-0049-0.
[30] I. Matsuya, Y. Honma, M. Mori, and I. Ihara, "Measuring liquid-level utilizing wedge wave," *Sensors*, vol. 18, no. 1, p. 2, 2017, https://doi.org/10.3390/s18010002.
[31] Y. Zhang, B. Zhang, L. Zhang, Y. Li, X. Gao, and Z. Liu, "Liquid level measurement model outside of closed containers based on continuous sound wave amplitude," *Sensors*, vol. 18, no. 8, p. 2516, 2018, https://doi.org/10.3390/s18082516.
[32] R. Reshma, U. Ramachandraiah, K. R. Devabalaji, and R. Sitharthan, "Liquid metal level measurement techniques," in *IOP Conference Series: Materials Science and Engineering*, 2020, vol. 937, no. 1, p. 12027, https://doi.org/10.1088/1757-899X/937/1/012027.
[33] Y. Singh, S. K. Raghuwanshi, and S. Kumar, "Review on Liquid-level Measurement and Level Transmitter Using Conventional and Optical Techniques," *IETE Tech. Rev. (Institution Electron. Telecommun. Eng. India)*, vol. 36, no. 4, pp. 329–340, 2019, https://doi.org/10.1080/02564602.2018.1471364.
[34] S. Wang, J. L. Corredor Garcia, J. Davidson, and A. Nichols, "Conductance-based interface detection for multi-phase pipe flow," *Sensors*, vol. 20, no. 20, p. 5854, 2020, https://doi.org/10.3390/s20205854.

[35] M. R. Hidayat, S. Sambasri, F. Fitriansyah, A. Charisma, and H. R. Iskandar, "Soft Water Tank Level Monitoring System Using Ultrasonic HC-SR04 Sensor Based On ATMega 328 Microcontroller," in *2019 IEEE 5th International Conference on Wireless and Telematics (ICWT)*, 2019, pp. 1–4, https://doi.org/10.1109/ICWT47785.2019.8978229.

[36] S. L. Mohammed, A. Al-Naji, M. M. Farjo, and J. Chahl, "Highly accurate water level measurement system using a microcontroller and an ultrasonic sensor," in *IOP Conference Series: Materials Science and Engineering*, 2019, vol. 518, no. 4, p. 42025, https://doi.org/10.1088/1757-899X/518/4/042025.

[37] N. Kumar, A. K. Dahiya, K. Kumar, and S. Tanwar, "Application of IoT in Agriculture," in *2021 9th International Conference on Reliability, Infocom Technologies and Optimization (Trends and Future Directions)(ICRITO)*, 2021, pp. 1–4, https://doi.org/10.1109/ICRITO51393.2021.9596120.

[38] I. M. Métrologie, "Water level detection system based on ultrasonic sensors HC-SR04 and ESP8266-12 modules with telegram and buzzer communication media," *J. homepage http//iieta. org/journals/i2m*, vol. 18, no. 3, pp. 305–309, 2019, https://doi.org/10.18280/i2m.180311.

[39] A. Karra, B. Kondi, and R. Jayaraman, "Implementation of Wireless Communication to Transfer Temperature and Humidity Monitoring Data using Arduino Uno," *Proc. 2020 IEEE Int. Conf. Commun. Signal Process. ICCSP 2020*, pp. 1101–1105, 2020, https://doi.org/10.1109/ICCSP48568.2020.9182139.

[40] P. Khoenkaw and P. Pramokchon, "A software based method for improving accuracy of ultrasonic range finder module," *2nd Jt. Int. Conf. Digit. Arts, Media Technol. 2017 Digit. Econ. Sustain. Growth, ICDAMT 2017*, pp. 10–13, 2017, https://doi.org/10.1109/ICDAMT.2017.7904924.

[41] V. Zhuk, L. Vovk, I. Popadiuk, and I. Matlai, "Discharge coefficient of rectangular broad-crested weirs in narrow channels with high relative length of the threshold," *Ecol. Eng. Environ. Technol.*, vol. 22, no. 6, pp. 11–16, 2021, https://doi.org/10.12912/27197050/141877.

[42] International Organization for Standardization, "ISO 3846," *International Organization for Standardization*, 2008, https://www.iso.org/standard/38065.html.

[43] A. L. Zuikov, V. V Bakunjaeva, T. V Artemyeva, and E. Y. Zhazha, "Flow states in the classical Venturi channel water gauge," *Mag. Civ. Eng.*, vol. 2, no. 78, pp. 76–90, 2018, https://doi.org/10.18720/MCE.78.6.

[44] ASTM International, "Standard Test Method for Open-Channel Flow Measurement of Water with Thin-Plate," *An Am. Natl. Stand. D 5242-95*, 2022, https://doi.org/10.1520/D5242-21.

[45] ASTM, "Standard Guide for Selection of Weirs and Flumes for Open-Channel Flow Measurement of Water," *ASTM Int. D5640-95*, 2014, https://allcivilstandard.com/wp-content/uploads/2019/02/D-5640.pdf.

[46] L. J. Bradley and N. G. Wright, "Optimising SD Saving Events to Maximise Battery Lifetime for Arduino^{TM}/Atmega328P Data Loggers," *IEEE Access*, vol. 8, pp. 214832–214841, 2020, https://doi.org/10.1109/ACCESS.2020.3041373.