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Real-Time Web Based Water Flow Detection Instrumentation System In Regional Water Servicein Indonesia

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ABSTRACT: *PDAM is a regional water service in Indonesia, mainly serves communities for clean water supply which is ready to drink. In obtaining the information about the amount of water consumption by the customer, it is required to install a measurement device in a point prior to every customer's own pipelining system, called a water flow meter. The available water flow meter used by PDAM, however, does not support real-time metering from remote location. This research sets its objective to solve the problem above, i.e. to develop a real-time measurement system that can be accessed anywhere by PDAM authorities.*
Electromechanical water flow meter will be used to obtain raw data, which then interpreted by microcontroller to produce water usage and flow velocity. The information is then sent to a database server and can be accessed through web browser by PDAM authorities in real time. The electromechanical water flow meter uses Hall Effect to send pulses to microcontroller. Arduino Uno is the microcontroller used, in conjunction with RTC (real-time clock), ethernet shield, and SD card reader. MySQL service is the database server which receives data from Arduino Uno and ethernet shield. In the web server, PHP is used to serve the client for displaying the data requested in a web browser. This research uses a method as sequenced below, namely system design, hardware construction, software development, system calibration, and system testing.
A result has been achieved after the sequence of method as calibration result and system testing result. For the calibration, it concludes that the system can maintain the accuracy of measurement as long as the calibrated hardware does not physically change. Moreover, the system operates well as the given specification.
KEYWORDS –*water flow meter, PDAM, arduino, ethernet, PHP.*

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I. Introduction

Almost every urban society in Indonesia is customer to PDAM (*Perusahaan Daerah Air Minum* – Regional Water Service in Indonesia).Every PDAM customer could be an individual or a legal business entity. In every PDAM customer's building, there is a water pipelining installation which delivers clean water to be directly consumed or stored in reservoirs. For finding out the information about the amount of water consumption by the customer, it is required to install a measurement device in a point prior to every customer's own pipelining system, called a water flow meter [1].

Currently, the water flow meter devices used by PDAM are mechanical water flow meters, which performs measurement of total amount of water volume flows since the time of device installation, while have a precision of 0.1 liter and measures up to 100,000 m^3. It can be concluded that for the benefit of PDAM on measurement accuracy, such measuring devices are already suitable. PDAM performsthe checkingof the gauge reading to determine the water usage of each period by comparing it with the previous period reading records.

There are some disadvantages of such device usage, as it is unable to measure the water flow rate consumed by customers and no real-time information can be read from remote location. The water flow rateinformation is also required to schedule water pumps operation for energy efficiency, as well as for predicting the trend of flow rate. The presence of a water meter field officer who has to perform inspections every day will greatly raise the operational cost on uneconomical level [2].Therefore, a system capable of measuring both the water usage and water flow rate that can be accessed remotely with high accuracy and in real-time by the authorities of the PDAM is a requirement.

II. Theoretical Basis

A. Fluids in Pipe

The flow of fluid in the pipe is influenced by several factors, namely the flow rate, the friction against the pipe, the fluid viscosity, and the fluid density. The volume of fluid flowing in a pipe with varying cross-sectional diameters will exactly be the same at each point. Debit is calculated from the volume of fluid divided by time, as in Equation (1).

$$Q = \frac{V}{t} \quad (1)$$

The fluid volume is calculated from the cross-sectional area multiplied by its length, as in Equation (2).

$$V = A \cdot s \quad (2)$$

Equation (1) and Equation (2) can be combined into Equation (3).

$$Q = \frac{A \cdot s}{t} \quad (3)$$

Fluid flow velocity is the change of distance (or length) over time, shown in Equation (4).

$$\vec{v} = \frac{s}{t} \quad (4)$$

If Equation (4) is substituted into Equation (3), then Equation (5) will be formed.

$$Q = A \cdot \vec{v} \quad (5)$$

In a closed pipe, the amount of flow velocity per cross section is always constant. If there is a difference in cross-sectional area of the pipe then the fluid flow velocity at the different cross section is shown in Equation (6) [3].

$$A_n \cdot \vec{v}_n = A_m \cdot \vec{v}_m \quad (6)$$

B. Mechanical Water Flow Meter

A mechanical water flow meter is a device used by the PDAM to record total water consumption by customer within a certain time period. The volume of water usage is displayed on the gauge shown on the water flow meter.

Fig. 1. A positive displacement meter.

This type of water flow meter basically measures the volume of water through the turbine inside the device. The turbine contained inside the sensor will rotate when there is a water flow. It is called as positive displacement meter (PD meter), as in Figure 1. The mechanical water flow metersdo not depend to power supply, and its gauge cannot be electronically or remotely accessed [3].

C. Electromechanical Water Flow Meter

Electromechanical water flow meter is a mechanical water flow meter device that uses electronic displays (or just a voltage pulse output) to replace mechanical gears. Typically, the type used is the PD meter, which uses the Hall Effect principle to count the turbine spin in the water flow [4].

D. Arduino Uno

Arduino is single-board microcontrollers for building digital devices and interactive objects that can sense and control objects in the physical and digital world. The project's products are distributed as open-source hardware and software, which are licensed under the GNU Lesser General Public License (LGPL) or the GNU General Public License (GPL), permitting the manufacture of Arduino boards and software distribution by anyone [5].

E. Ethernet Shield

The Arduino Ethernet shield 2 allows an Arduino board to connect to the internet using the Ethernet library and to read and write an SD card using the SD library. Depending on the shield version, using the proper library is a requirement, as documented in the Ethernet library page [6].

F. PHP

PHP is a server-side scripting language designed for web development but also used as a general-purpose programming language. Originally created by Rasmus Lerdorf in 1994, the PHP reference implementation is now produced by The PHP Group. PHP originally stood for Personal Home Page, but it now stands for the recursive acronym PHP Hypertext Preprocessor [7].

III. Method Of Research

Method used in this research is shown in Figure 2, which goes through several stages explained below.

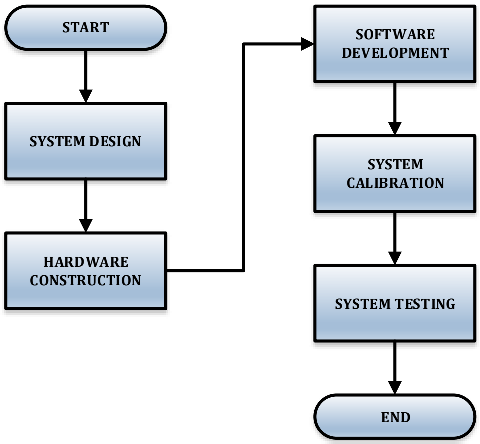

Fig. 2. Diagram of Research Method.

A. System Design

This stage contains several test subject points of data flow, i.e. water flow meter, Arduino, storage, ethernet shield, and database server. The test object points will be measurement accuracy, water flow meter connection to Arduino, and internet connection. The test of data flow logic will be performed until the valid one received by server. In the case of internet connection error, the valid unsent data must be retransmitted when the connection reestablished.

B. Hardware Construction

This stage is to construct the hardware based on the previous one. The components used are the physical hardware, therefore the result will be a real-world application rather than a simulation. The hardware to be constructed must be able to measure the real water flow, as well as the data acquisition and remote access. The data sent via real internet connection to certain database and web server hosting.

C. Software Development

Software development process will be performed after the specified hardware constructed and connected into water flow meter and the internet. This stage is divided into two parts, namely:

1. Programming in microcontroller, which will be done using Arduino IDE 1.8 and C++ programming language; and
2. Programming in web server using PHP.

D. System Calibration

After software development stage, a calibration test will be performed to know whether the system meet its objective, especially in user interface prior to implementation. The points below are the calibration test which will be performed:

1. In this experiment, a hardware test is performed in calibration phases.
2. In the mean time, a calibration procedure is assembled by means of choosing ordinary user to read the procedure.

E. System Testing

These properties indicate the testing success:

1. The calibrated measurement data written in the server has maximum error of 5% compared to the manual measurement.
2. Arduino warns in case of connection problem with water flow meter.
3. Unsent data due to internet connection problem must be completely resend after the connection reestablished.

IV. Results And Discussions

A. Design and Construction of Hardware

In accordance with the diagram that has been described in the framework of the concept of research, it will be shown a special design on the hardware. Figure 3 shows the design to be applied to the hardware block.

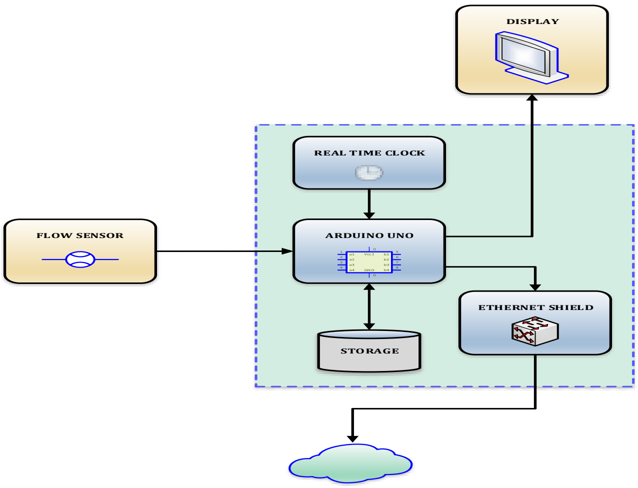

Fig. 3. Design in hardware block.

This section discusses the elements of hardware blocks assembly and how it work one by one. The composing elements to be discussed along with the data models to be exchanged include: Hall Effect sensor device, RTC device (real-time clock), LCD used to display, SD card as storage media, and ethernet shield device.

As shown in Figure 4, the turbine inside the device is exposed by the water flowing from the pipe on one side to the opposite one, which then cause the turbine to spin. The turbine number of turns will be proportional to the volume of water flowing.

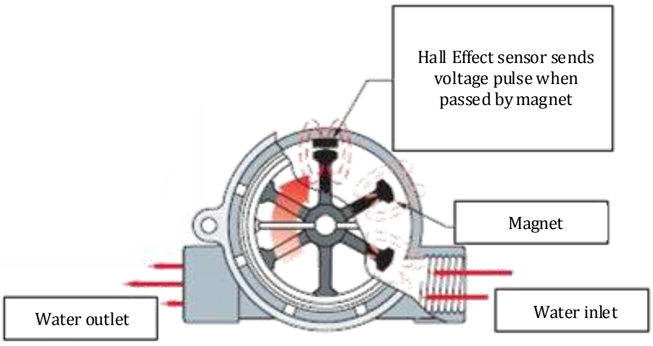

Fig. 4. Hall Effect sensor working principle.

A magnet is mounted to the one blade of the turbine, causinga Hall Effect which generates a voltage pulseevery time the turbin turns [8].The transmission of the voltage pulse to the Arduino Uno is carried out on pin 2,and is monitored continuously by pooling.

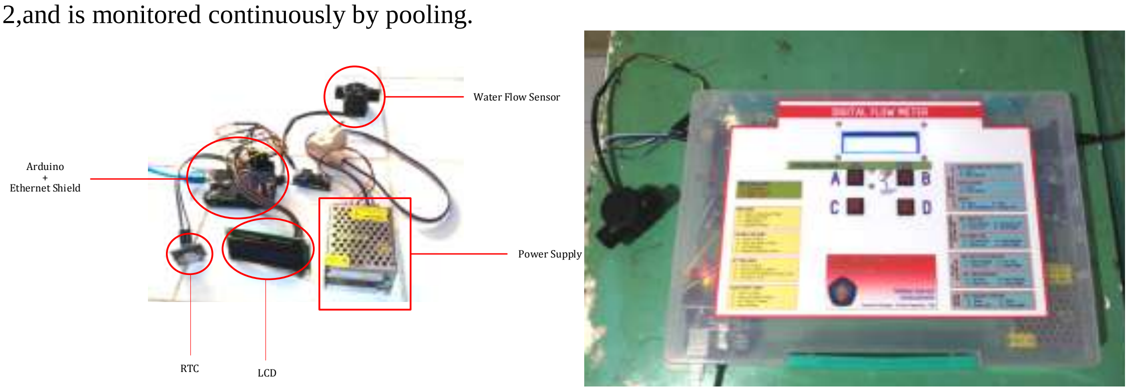

Fig. 5. The unassembled and the final assembly of hardware block.

The hardware block shown in Figure 5is the final assembly of this research, after the design described in Figure 3 previously. Figure 6 shows the shape of HIGH (+5 V) pulses occurring in real world, with finite interval of voltage rise from LOW (0 V) to HIGH, finite interval to stay at the HIGH, and finite interval of voltage drop back to LOW. This finite time operation will be used to detect the pulse in the form of LOW-HIGH-LOW state sequence [9].

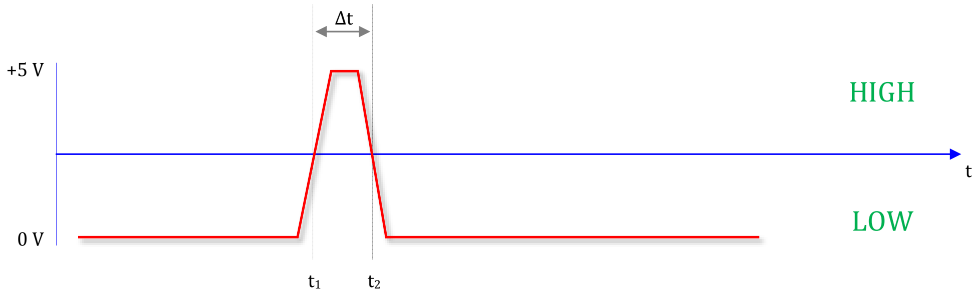

Fig. 6. A time diagram of a real 5 V pulse with its finite time delay.

Equation (7) shows the relationship between time measurement with time interval.

$$\Delta t_{pulse} = t_2 - t_1 \quad (7)$$

Since pooling method is used for pulse detection, then the process speed of Arduino becomes very important. The time required from between two sequence of pooling should be smaller than the pulse interval, precisely it must be at least half of the time between pulses, as in Equation (8) and Equation (9) [9].

$$\Delta t_{pool} \leq \frac{\Delta t_{pulse}}{2} \quad (8)$$

$$\Delta t_{pool} = t_{next} - t_{prev} \quad (9)$$

Therefore, it should be ensured that the pooling process is briefer than half the pulse interval. The water flow velocity relationship with the interval time between pulses and calibration constant is shown in Equation (10) [6].

$$Q = \frac{1}{k \cdot T_{pulse}} \quad (10)$$

The second technique replaces pulse period by pulse frequency, as in Equation (11) which explains the relationship of water flow velocity with pulse frequency and calibration constant [9].

$$Q = \frac{1}{k} \cdot f_{pulse} \quad (11)$$

Figure 7 shows the algorithm to obtain the frequency using the second technique. The calibration constant will be determined with the number of pulses per one liter of flowing water. The main algorithm is to pool with definite time interval (e.g. 200 ms) and record the number of pulses, then report the value. If there is no pulse in that time, the frequency is simply reported as zero.

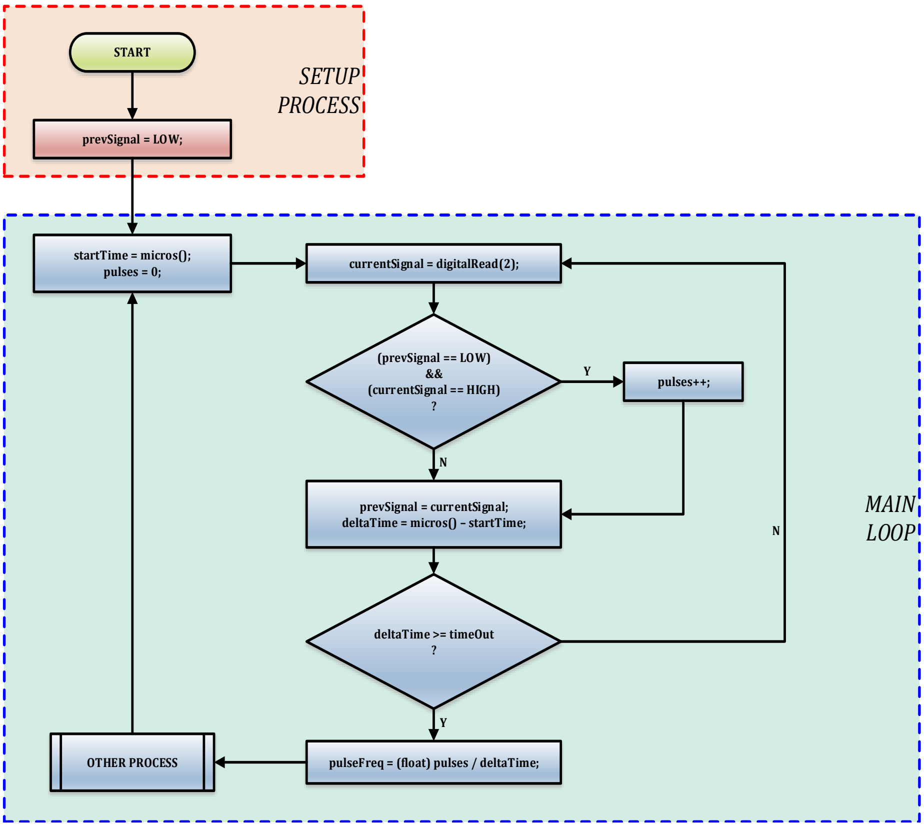

Fig. 7. An algorithm to obtain pulse frequency.

The RTC device used in this study is DS3231, which is capable to store timekeeping data with high accuracy and has precision of up to one second. Arduino will get timestamp information from RTC and combines with the flow data to send to server. To display real-time data on the hardware block side, an LCD is used. Prior to its delivery, the combined timestamp and flow data must be stored on an SD card.

B. Programming of Hardware

The program in Arduino Uno has a variety of functions, and the algorithm has been discussed by Figure 7,while the sub-algorithm for interpreting raw data from the sensor at the water flow meter to the pulse frequency has been described earlier [10].

C. Programming on Server

Programming on the web server is intended to have data that has been stored on the database server can be accessed by authorized users through a web browser.

D. System Calibration

The calibration process is performed to get the calibration constant, which will be stored on the SD card or EEPROM. According to Equation (11), the calibration constant will be obtained from the total pulses obtained from every one liter of water flowing.

TABLE I. CALIBRATION RESULT

t_1	t_2	Pulse									
		K-1	**K-2**	**K-3**	**K-4**	**K-5**	**K-6**	**K-7**	**K-8**	**K-9**	**K-10**
0	1	21	20	20	21	12	11	20	20	21	21
1	2	20	20	20	21	21	21	20	20	21	20
2	3	20	20	21	21	21	21	20	21	21	20
3	4	20	20	21	20	21	21	20	20	21	21
4	5	20	20	20	21	21	21	21	20	21	21
5	6	20	20	20	21	22	21	21	19	21	21
6	7	20	20	20	21	21	21	20	20	21	21
7	8	17	19	21	12	21	21	20	20	7	16
Total Pulse		**158**	**159**	**163**	**158**	**160**	**158**	**162**	**160**	**154**	**161**

According to Table I, the calibration performed with the water valve in opened position and the volume of water is one liter turned out to take the average of 159 pulses.

E. System Testing

The system testing has performed by compare real water flow (as gauge reading on mechanical PD meter) with the data sent to the server. Every testing lets 1000 ml of water flown through the hardware block.

TABLE II. TESTING RESULT

No.	Time (s)	Pulses	Volume (ml)	Flow Rate (ml/s)	Error	Squared Error	Persen Error
1	6	182	1145.00	190.83	145.00	21025.00	14.50
2	5	156	978.00	195.60	-22.00	484.00	-2.20
3	6	154	969.00	161.50	-31.00	961.00	-3.10
4	5	189	1190.00	238.00	190.00	36100.00	19.00
5	6	172	1083.00	180.50	83.00	6889.00	8.30
Total (SSE)						**65459.00**	
Average (MSE)						**114.42**	**11.44**

As shown in Table II, the testings generated MSE of 114.42 ml. It corresponds with 11.44 percent of error, less than 25% expected.

V. Conclusion

Based on the test results,a conclusion has been obtained, that a system for measuring water flow velocity and water volume usage has been developed by using electromechanical water flow meter, microcontroller, RTC, ethernet shield, and web infrastructure. The real-time information of water usage can be sent electronically to remote computer via internet connection with 0.1 liter volume precision and one second time precision. And based from the testing, the comparation between real-world and hardware measurement delivers result as MSE of 114.42 ml (11.4%).

Meanwhile, two propositions can be given as to expect the next research to obtain backup system in case of power failure occurs on the hardware block, and to expect that subsequent research can perform data compression for sending and storing in database server.

References

[1]. Badan Standarisasi Nasional. (2005). Spesifikasi Meter Air Minum. Bandung: Badan Standarisasi Nasional.
[2]. Suharjono, A., Rahayu, L., & Afwah, R. (2015). Aplikasi Sensor Flow Meter untuk Mengukur Penggunaan Air Pelanggan Secara Digital serta Pengiriman Data Secara Otomatis pada PDAM Kota Semarang. Jurnal TELE, Vol. 13, No. 1.
[3]. Sood, R., Kaur, M., & Hemant, L. (2013). Design and Development of Automatic Water Flow Meter. IJCSEA, Vol. 3, No. 3.
[4]. Naik, A., & Waghmare, A. (2015). Water Velocity Measurement using Contact and Non-Contact Type Sensor. IEEE.
[5]. Arduino - Home. (2017, 5 9). Retrieved from Arduino: https://www.arduino.cc
[6]. Arduino Ethernet Shield 2 - DEV-11166. (2016, 10 3). Retrieved from SparkFun Electronics: https://www.sparkfun.com/products/11166
[7]. PHP: Hypertext Preprocessor. (2016, 10 8). Retrieved from PHP: Hypertext Preprocessor: http://www.php.net/
[8]. Sungkono. (2006). Pemanfaatan Hall Effect Sensor sebagai Penghitung Konsumsi Air. Jurnal Eltek, Vol. 4, No. 1.
[9]. Rachmad, S. (2008). Teknik Akuisisi Data. Yogyakarta: Graha Ilmu.
[10]. Riley, M. (2012). Programming Your Home Automate with Arduino, Android, and Your Computer. LLC: The Pragmatic Programmers.

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