Research of water flow measuring device based on Arduino platform

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Abstract. The article provides information about modern methods and devices for measuring water flow in pipes in the irrigation system. To create a device suitable for an automated system for calculating water flow in pipes, and sending information about water flow via Bluetooth and GPRS module, the possibility of using the base of the Arduino platform was considered. A YF-S201 transducer was used to determine the water flow in the pipe. The article presents the experiment results based on a laboratory stand. Based on the Arduino UNO board and laptop, the measurement results were processed, as well as the remote transmission of data and their visualization on a smartphone. The linearity and error of the static characteristic of the proposed water flow detection device were investigated.

1 Introduction

Inadequate use of water resources is one of the main reasons preventing the sustainable development of irrigated agriculture in Uzbekistan. Experts say that the decrease in the productivity of agricultural crops, and some cases the loss of crops, is related to the problem of water shortage. To improve this situation, effective technologies are needed to prevent the irrational use of water resources in irrigation systems [1].

Therefore, this article focuses on improving water flow measurement and control devices. In the process of supplying water to agricultural crops, water resources are transferred through pipes and open channels [1]. In these facilities, various measuring methods and tools, such as water flow and water level, are used to measure quantities.

The most common method for measuring water flow in pipes is the method of velocity-area. When measuring water flow at pumping stations, graduated hydromechanical devices are used, i.e., devices such as spiral chambers and piping devices, suction nozzles of pumping units, etc. However, the measurement accuracy of these measurement methods depends on several factors determined during metrological certification [12].

The partial method for measuring water flow at high-pressure flows is also common. "Partial" methods are used to determine the water flow in high-pressure flows in two ways:

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as an independent method and in conjunction with a set of compression devices. In both versions, it is structurally used as a pipe or channel of a small diameter parallel to the main flow. Due to the low accuracy of this method, it is recommended to use it as an indicator of water flow [12].

As is known, the determination of water flow by the "velocity-area" method is based on the measurement of two parameters. These parameters are the average water velocity and the cross-sectional area of the flow. These two parameters are determined using different measuring instruments or different measurement methods. Geodetic methods are used to measure the cross-sectional surface of a flow, while level sensors or hydrostatic pressure sensors are used in stationary flows. To determine the average flow velocity, hydrometric oars (turntables) and ultrasonic and electromagnetic measuring sensors are widely used. Currently, the most common speedometers are hydrometric paddles. Three methods are mainly used to determine the average flow rate with their help. These are multipoint, complex, and single-point measurement methods [3,12,13,14].

Although using hydrometric paddles has advantages such as structural simplicity and ease of operation, the main disadvantage of this method is the large amount of work, the complexity of full automation, and sensitivity to existing stones and other impurities in the stream [3, 7].

In recent years, ultrasonic (acoustic) measuring instruments have been widely used abroad and in our country. Such measuring sensors effectively helps full automation or remote data transmission [4,5,6]. But the practical use of such sensors requires the full supply of channels with electricity. In addition, the prices for ultrasonic measuring sensors are high, their errors in measuring the flow of dirty water are quite large, and their operation requires high qualifications [8].

Today's demand requires measuring instruments with high accuracy and sensitivity, small size, energy-efficient, and easy to computerize.

These requirements are met by water flow meters based on the Arduino platform and the Hall effect, which are very reliable and easy to operate.

2 Methods

Today, the Arduino platform is used in many different projects. Scientific researchers can use it to create interactive prototypes. It helps to show investors what the finished project might look like. There are different types of Arduino platforms; they differ from each other in processor, microcontroller, and digital and analog outputs (pins), more or less [17].

There is a need for inexpensive, accessible methods and means of controlling water consumption in agriculture and scientific research. For this reason, the authors conducted scientific research on developing inexpensive instruments that allow measurements to be made with sufficient accuracy. This research paper explored the possibilities of using the Arduino Uno platform to create a modern device for determining water flow.

The water flow meter, developed based on the Arduino platform, includes several components, as shown in Figure 1.

The sensitive element of the device for measuring water flow in pipes is an impeller rotating due to the flow of liquid. The principle of operation of such flowmeters is based on measuring the wheel rotation speed, which is proportional to the flow rate of the measured medium [11,15].

Wheel flow meters are designed to measure the flow of liquids of low and medium viscosity (water, gasoline, kerosene, diesel fuel, alcohols, aggressive liquids, etc.), as well as gas flow.

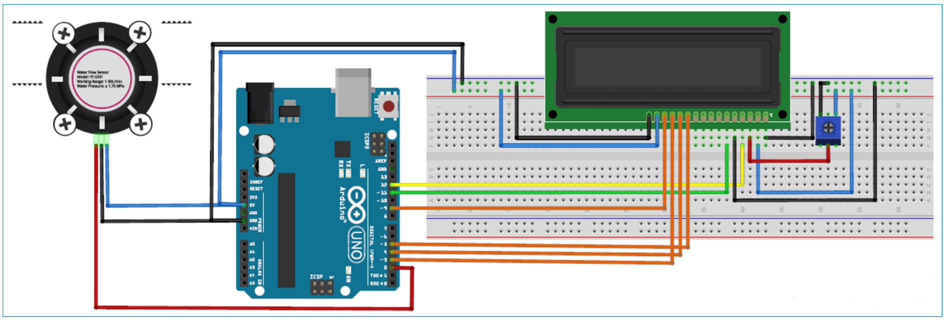

Fig. 1. Scheme of water flow detection device based on Arduino board.

Measurement of wheel speed (or the number of revolutions, which is also proportional to the flow rate) can be made by contact and non-contact methods. The contact method connects the wheel directly to the rev counter. The non-contact method is based, for example, on using Hall effect detectors. The contact method for measuring wheel speed is characterized by energy losses, which leads to significant measurement errors. Non-contact speed measurement reduces energy losses [14].

Fig. 2 shows a schematic diagram of a turbine flow meter. The flow meter includes a paddle wheel, a sensitive element for measuring the wheel's rotation speed (number of revolutions), and consumption rectifiers [13,14]. For the flowmeter to work without problems (without errors), there must be no turbulence (accumulation) in the fluid flow entering the turbine. These special elements are provided by the presence of flow straighteners (straight water straighteners).

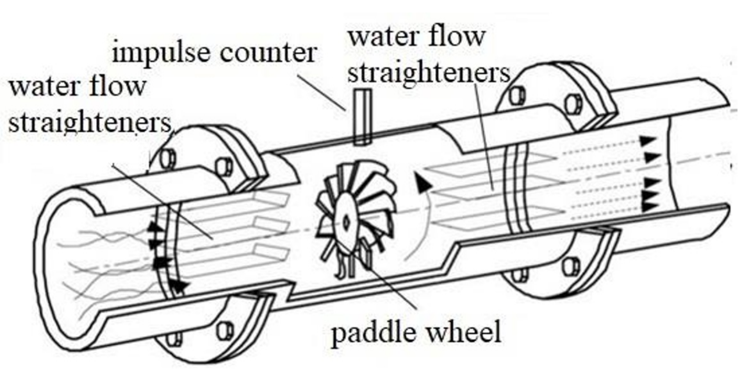

Fig. 2. Construction of turbine flow meter

Fig. 3 shows design options for vane flowmeters. The principle of operation of such devices is as follows. Permanent magnets are located on each wheel blade. When the magnetic blade passes by the Hall element, it generates an output signal (voltage pulse) [16]. Thus, the pulse frequency is proportional to the water flow. The Hall element signal is processed by the circuit and can be converted to any standard output signal.

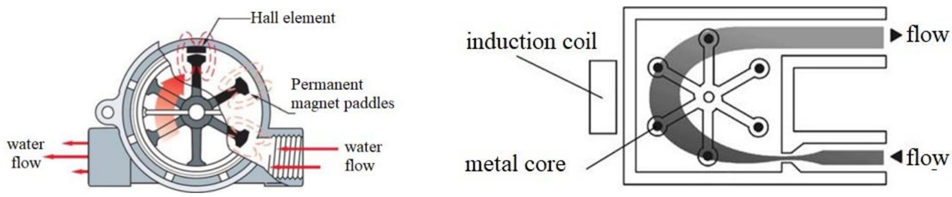

Fig.3. Construction of paddle wheel flow meter is based on Hall effect.

Fig. 4 shows a Faure Hermann turbine meter and a Gems wheel meter.

Fig.4. Flow meters based on Hall effect of "Faure Herman" and "Gems" companies

Advantages of turbine flow meters:
• simplicity of construction;
• wide measurement range;
• small inertia;
• almost linear calibration characteristic;
• the ability to measure the flow of liquids and gases.
Disadvantages of turbine flow meters:
• significant dependence of the measurements on the viscosity of the measured medium;
• failure of the rotating parts of the sensor can lead to deterioration of its metrological properties and a decrease in service life.
YF-S201 water flow transducer
This flow transducer model has a paddle wheel that rotates under water pressure. The transducer works based on the Hall effect, in which a pulse is generated at each rotation of the paddles. The Hall transducer is hermetically separated from water and paddles, so water does not leak into the Hall transducer [20].
The flow transducer has three conductors (wires): red (5-24V direct current), black (ground), and yellow (output signal from the Hall sensor). Water flow can be easily calculated by counting pulses from the output of the transducer. Each pulse is about 2.25 milliliters. Please note that this calculation cannot be considered an absolute accurate information, and the pulse frequency varies depending on the flow rate, ambient pressure, and the direction of the transducer in the field [11,15].
The signal from the transducer can be easily converted to liters using the following formula:
Pulse repetition frequency (Hz)/7.5 = water flow, l/min.
Connecting to the Arduino Platform:
• The red wire is connected to the + 5V source;
• The black wire (GND) is connected to the ground;
• The yellow wire is connected to the output of the switch.
Characteristics:

• Operating voltage: 5V to 18V
• Maximum current: 15 mA
• Output: 5 V TTL
• Working range of the transducer: 1 to 30 l/min
• Operating temperature range: -25 °C to + 80 °C
• accuracy: ± 1%
• Maximum water pressure: 2.0 MPa
• 1 liter water output: 450 pulses;
• Cable length: 25 cm
• Diameter: 1/2" pipe connection, 0.78" outer diameter, 1/2" thread diameter
• Insulation resistance ≥ 100 MOm

The change in the frequency of the output signal of the converter directly depends on the flow of liquid (Fig. 10).

3 Results and discussion

In the scientific research work, the improvement of water and energy efficiency using the improved version of the device for measuring water flow in the pipelines of pumping stations is provided, and the following works were carried out in the department's laboratory.

The following equipment was used for this: Arduino platform, screen, battery, tube, Hall transducer (YF-S201), magnet, flywheel, and connecting wires [17].

In this scientific research work, a model of a water flow measuring device was prepared (Fig. 5). In this model, the water flow was pumped from the reservoir of the pumping station through a pressure pipe to the open well in a closed cycle, and then again through a self-flowing pipe to the reservoir of the pumping station.

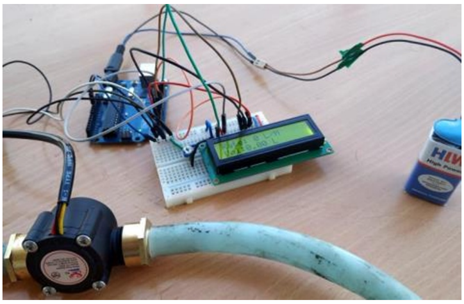

Fig. 5. Design of researched water flow measuring device

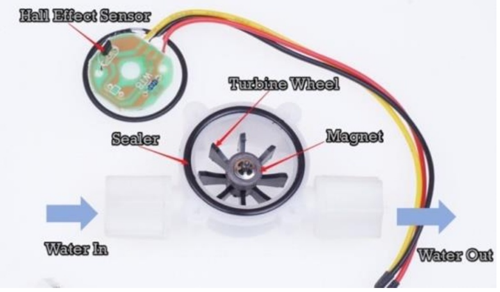

Fig. 6. YF-S201 model transducer

Sealer – stuffing box (a detail that closes the slits, a coating); **Turbine wheel**; **magnet**; **Hall effect sensor**; **Water in** – water flow inlet; **Water out** – water flow outlet.

The working principle of the water flow measurement transducer is very simple. The main components are the Hall element, the flywheel, and the magnet. The water flow turns the wheel, and the magnet in the wheel turns with it. The rotation of the magnetic field activates the Hall transducer, which emits high and low-level square waves (pulses) [17,19].

Fig. 7. YF-S201 Hall transducer operation

Like the number of rectangular waves produced by each wheel revolution, the water flow has a certain amount of volume. Therefore, we can calculate water flow by counting the number of rectangular waves (pulses) [19].

3.1 Using the water flow transducer with the Arduino platform

Necessary equipment (materials) for the device [17]
- Arduino Uno platform;
- Transducer for measuring water transducer;
- Wires to connect them together.

The water flow measurement transducer is connected through the pins of the Arduino UNO platform. We use pin D2 to detect the pulses at the output of the water flow measuring transducer. After connecting the transducer with the platform, it is necessary to create a program through the computer and load it.

Of course, we can use DigitalRead() in the LOOP function to read the signal at the flowmeter output. When the signal is high, add one digit each time. However, this approach does not work in real-time, and the program needs a certain amount of time to wait for each execution until new pulses appear. For such demanding real-time applications, we usually use interrupts. When the rising edge of the pulse is detected, an extra count is made, and the interrupt is triggered.

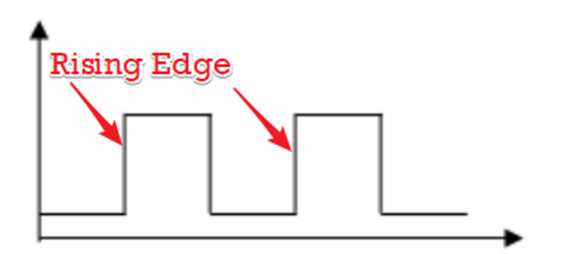

Fig. 8. Transducer output signal

3.2 Mathematical model of water flow calculation

l_hour = (flow_frequency*60/7.5)

As we mentioned above, the volume of the water flow is determined with each wheel revolution. At the same time, the number of pulses generated during wheel rotation is also a certain value. So we can form an equation between the number of pulses and the water flow.

For example, for the YF-S201, the Hall transducer generates 450 pulses for each liter of flowing water. Let's get acquainted with the process of calculating water flow. The transducer we are considering needs to generate 450 pulses per liter of water, so each pulse means that 1/450 of a liter of water is flowing. For V_total (liters), we get the total volume of liquid flowing through the water flow transducer at a certain time t (seconds), and for N, we get the total number of detected pulses. Then we have:

$$V = N \cdot \frac{1}{450} \tag{1}$$

V_total(L) = N* 1/450(L)
In addition, the total volume of water flowing through the water flow transducer is equal to the water flow (Q-liters/second) multiplied by the time t (seconds).

$$V = Q \cdot t \tag{2}$$

V_total(L) = Q(L/s)*t(s)
Substituting (2) into (1), we get the following expression:

$$N \cdot \frac{1}{450} = Q \cdot t \tag{3}$$

$$\frac{N}{t} = 450 \cdot Q$$

N*1/450 = Q(L/s)*t(s); N/t = 450 * Q(L/s)
N/t - f - f represents the frequency, so:

$$f=450 \cdot Q \tag{4}$$

From expression (4), we create the formula for calculating water flow in the pipe:

$$Q(L/s) = \frac{f}{450}; \tag{5}$$

$$Q(L/\min) = \frac{f \cdot 60}{450} = \frac{f}{7.5}; \tag{6}$$

$$Q(L/\text{hour}) = \frac{f \cdot 60 \cdot 60}{450} = \frac{f \cdot 60}{7.5} \tag{7}$$

According to the test results, the average water consumption value was equal to Q=0,58875 m^3/s.

3.2 Improved measuring device converter error research

Error is one of the main characteristics of measurement. According to state standard 1626-3-70, measurement error is the deviation of the measurement results from the actual values of the measured quantities. For the actual value of the measured quantity, the value that can be determined using standard measuring instruments is accepted. Sometimes the concept of the accuracy of measuring tools is used, which indicates that the errors of measuring tools are close to zero and reflects their quality [9,10].

During the test experiment, the flow rate was also controlled at different points of the pipe section. According to the mathematical requirements of the tested water flow measuring device, its speed differed by ±0,1-0,5 % from the actual profile of speed distribution along the flow section. In addition, water streams with different levels of pollution and temperature were discharged from the pipe, and the measurement results showed the same value as in clean water.

The graph below shows the result of the experiment of the measurement error of the device transduser prepared in the scientific research work.

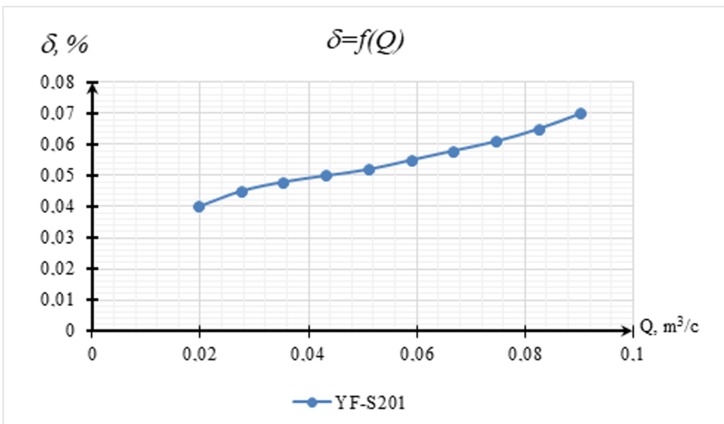

Fig. 9. Errors of measuring transducers

It is known from the graph that the average error of the transducer is 0.5%. The mentioned error is not considered a major error in our conditions.

We construct the static characteristic of the transducer according to expression $f(Q)=46.14\cdot Q(1-0.002/Q^2-0.017/Q^{0.5})$:

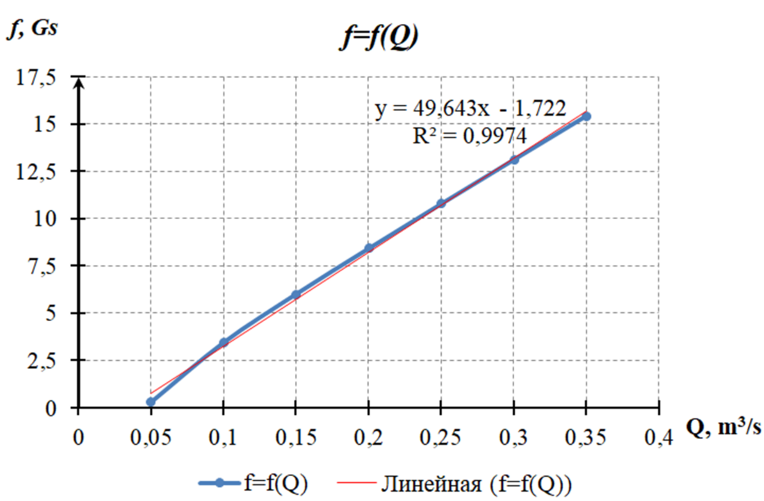

Fig. 10. Dependence of output signal frequency of transducer on water flow

From the static characteristic of the converter, it is known that the transducer has a linear characteristic. Based on these results, we recommend using the water flow measuring device based on the Hall effect in the water supply systems of our country.

4 Conclusions

The Arduino Uno platform was chosen to convert, receive, store, transmit and process water flow signals into digital signals at pumping stations.

During the experiments, it was confirmed that the Arduino platform meets the requirements of the technological processes of the pumping stations.

The analysis of the measuring transducer based on the Hall effect showed that it differed from other measuring transducers due to its simple structure, wide measuring range, ease of connection to EHM, and water flow calculation suitable for use in a measuring device.

Considering the availability of the Arduino platform in our country and its low price, it is recommended to use the water flow measuring device based on the Arduino platform proposed for determining water flow at pumping stations in water management networks, as well as in the educational process.

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