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ULTRASONIC FLOW METER CALIBRATION VIA THE INTERNET USING AN ANALOG-TO-DIGITAL CONVERTER

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Abstract: *The purpose of scientific research work is remote control of improving the metrological properties of the water flow measuring device. Therefore, the Arduino platform with an additional ESP8266 NodeMcu v3 and analog-to-digital converter, module was installed in the scientific article for automatic calibration/checking of ultrasonic flow meters used in irrigation networks. The module is integrated into a 32-bit microcontroller with low power consumption. The ESP8266 NodeMcu v3 module operates at 80 and 160 MHz clock frequencies, supports real-time operating system (RTOS), built-in Wi-Fi, and has a microstrip antenna on board. Through this, the data exchange between the computing equipment and the flow meter was carried out wirelessly. The module was also used as an HTTP server. Metrological and other information exchange was carried out using GET and POST requests. The mentioned devices performed the given task correctly and qualitatively.*
Keywords: *Arduino, ultrasonic flow meter, microcontroller, server, module, program, code, ESP8266 NodeMcu v3, HTTP, Wi-Fi.*

Annotatsiya: *Tadqiqot ishining maqsadi suv sarfini o'lchash qurilmasining metrologik xususiyatlarini yaxshilashni masofadan boshqarish etib belgilangan. Ishda sug'orish tarmoqlarida qo'llaniladigan ultratovush sarf o'lchagichlarni avtomatik kalibrlash/tekshirish uchun analog-raqamli konvertor va Arduino platformasi bilan qo'shimcha ESP8266 NodeMcu v3 modulidan foydalanilgan. Modul past quvvat sarfiga ega 32 bitli mikrokontrollerga birlashtirilgan. ESP8266 NodeMcu v3 moduli 80 va 160 MGts taktli chastotalarida ishlaydi, real vaqtda operatsion tizimni (RVOT), o'rnatilgan Wi-Fi funksiyasini qo'llab-quvvatlaydi va platasi mikrotasma antennaga ega. Bu orqali hisoblash texnikasi va sarf o'lchagich o'rtasida ma'lumot almashish simsiz amalga oshirildi. Moduldan HTTP serveri sifatida ham foydalanildi. Metrologik va boshqa ma'lumotlar almashinuvi GET va POST so'rovlari yordamida amalga oshirildi. Qayd etilgan qurilmalar berilgan vazifani to'g'ri va sifatli bajardi.*
Tayanch so'zlar: *Arduino, ul'tratovushli sarf o'lchagich, mikrokontroller, server, modul, dastur, kod, ESP8266 NodeMcu v3, HTTP, Wi-Fi.*

Аннотация: *Цель исследования состоит в дистанционном контроле за улучшением метрологических характеристик прибора для учета расхода воды. В работе была использованы платформа Arduino с дополнительным модулем ESP8266 NodeMcu v3 и аналогово-цифровым преобразователем для автоматической калибровки/поверки ультразвуковых расходомеров, используемых в оросительных сетях. Модуль интегрирован в 32-битный микроконтроллер с низким энергопотреблением. Модуль ESP8266 NodeMcu v3 работает на тактовых частотах 80 и 160 МГц, поддерживает операционную систему реального времени (ОСРВ), встроенный Wi-Fi и имеет на борту микро полосковую антенну. Благодаря этому обмен данными между вычислительным оборудованием и расходомером осуществлялся беспроводным способом. Модуль также использовался в качестве HTTP-сервера. Обмен метрологическими и другими данными осуществлялся с использованием GET и POST запросов. Указанные устройства правильно и качественно выполнили поставленную задачу.*
Ключевые слова: *Arduino, ультразвуковой расходомер, микроконтроллер, сервер, модуль, программа, код, ESP8266 NodeMcu v3, HTTP, Wi-Fi.*

Introduction

In recent decades, the development of ultrasonic flowmeters has been increasing rapidly in developed countries. There are three main types of ultrasound methods for measuring fluid volume flow: Doppler, time-pulse and correlation methods. The choice of a specific measuring method depends on the object and the type of measuring tool.

The Doppler measurement method is most suitable for measuring fluid flow in various environments. In fact, the use of this method in open irrigation systems is technically difficult. The Doppler method is based on the change of frequency in the medium of the object [3,5,11,13].

The time-pulse measurement method is most suitable for measuring fluid flow in the same environment. This method is based on sending ultrasonic signals along and against the flow of liquid into the acoustic channel of the flow meter. The flow rate is determined by the difference in the movement time of the signals. This method has high measurement accuracy and the ability to ensure reliable operation of flow meters.

The correlation measurement method is based on the principle of determining the time of movement of the uniformity of the flow between two measuring sections of the pipeline. The time elapsed between the appearance of signals with approximately the same modulation in different measuring sections is directly proportional to the fluid velocity [2].

The advantages of this measurement method are as follows: ensuring that the quality of measurements is less dependent on the physical and chemical properties of the liquid, the condition of the pipeline, the distribution of velocities along the flow section, and the accuracy of the installation of primary transducers in the pipeline.

The most important functional units of ultrasonic flowmeters are transmitters and receivers (transducers) of ultrasonic waves, which mainly determine the operational capabilities and technical level of the devices.

Often, transmitter-receivers are manufactured on the basis of piezoceramic elements [4], and the construction and technical characteristics of piezoelectric conductors are usually not given in the documents of domestic and foreign manufacturers.

Research methods. In this research, we used a time-impulse ultrasonic flow meter for irrigation networks, the principle of which is to measure the time of movement of ultrasonic pulses in the direction of water flow in the pipeline and against it [5].

The pulses are triggered by piezoelectric transducers [4] installed in the housing of the flow meter. The electronic unit controls the ultrasonic receiver transmitters, receives signals, processes, transforms and transmits them to the computing device, which includes information on the propagation time of ultrasonic pulses [1] necessary to calculate the volume consumption of water under operating conditions takes:

$$v = \frac{L \cdot (t_2 - t_1)}{2t_1 t_2 \cdot \cos\alpha} \tag{1}$$

Here, v – water flow rate in the pipe, L – the distance between the transmitters and receivers of signals, α − the angle between the sensor mounting axis and the pipeline axis, t_1 and t_2 - are the propagation times of ultrasonic pulses in accordance with the flow and against the flow.

The signals were transmitted to the computing device via USB cable or Wi-Fi wireless communication system.

Previously, a personal computer (PC) running Windows operating system (OS) was used as a computing device. For this, there were a number of inconveniences associated with the organization of wired communication and the use of USB-COM devices, as well as the need to install different drivers for each OS version.

Our purpose was to simplify the process of connecting a flow meter to a computer and expand the range of devices for processing and storing metrological information.

We have installed an additional ESP8266 NodeMcu v3 module on the Arduino platform [1] to achieve the objective of this research work. The module is integrated into a 32-bit microcontroller with low power consumption. The ESP8266 NodeMcu v3 module operates at 80 and 160 MHz clock frequencies, supports real-time operating system (RTOS), built-in Wi-Fi functionality, and has a microstrip antenna on board [10].

The module supports the IEEE802.11 standard, a complete set of TCP/IP protocols. The module can be used as an add-on for connecting the device to a network or as a separate network controller [6].

To program the ESP8266 NodeMcu v3 module, we downloaded additional files to work with the Wi-Fi communication system [12,14,15,16,17] and selected the Arduino IDE program. Arduino and Arduino compatible boards are designed to be expandable as needed by adding new components to the device. These expansion devices are connected to the Arduino board via pin connectors [1].

There are a number of boards with a single design that allow the CPU board and expansion cards to be connected systematically via the pin lines in the kit [7].

There are also small footprint boards (e.g. Nano, Lilypad) and special designs for robotics tasks.

Microcontrollers for Arduino are distinguished by the presence of a pre-flashed bootloader. This loader loads the program into the microcontroller without the need for traditional separate hardware programmers. The bootloader is connected to the computer using a USB interface or a separate UART-USB adapter. Bootloader support is built into the Arduino IDE and is done with a single mouse click [1,8].

If you rewrite the bootloader or buy a microcontroller without a bootloader, the developers provide the option to enable the bootloader on the microcontroller yourself. To achieve this, the Arduino IDE has built-in support for several popular low-cost programmers, and most Arduino boards have a header for electronic programming.

You can compile and load the template program for the ESP8266 NodeMcu v3 module directly from the Arduino IDE, resulting in a single-board circuit that supports Wi-Fi.

The Arduino programming language belongs to the standard C++ language (using the AVR-GCC compiler) and has some peculiarities.

Programs written on Arduino are called sketches and are stored in files with the ino extension. These files are processed by the Arduino processor before compilation. There is also an option to create and link standard C++ files to the project. The Arduino preprocessor creates the main() function required in C++ by inserting the necessary "draft" operations there. It is not necessary to include the header files of the standard libraries used in the body of your program. These header files are added by the Arduino processor according to the project configuration.

The Arduino IDE project manager has a non-standard mechanism for adding libraries. Libraries in the form of standard C++ source code are added to a special folder in the IDE's working directory. This will add the library name to the list of libraries in the IDE menu. The programmer defines the necessary libraries and they are added to the compilation list [1].

Results. In the research work, the ESP8266 NodeMcu v3 module played the role of an access point and the Wi-Fi network it created [12,14] was visible during a standard search for networks on personal computers or mobile devices. Information about the propagation time of the ultrasonic pulses was transmitted to the ESP8266 NodeMcu v3 module via an asynchronous serial interface. The module provided pre-processing of this information and subsequent transmission over the Wi-Fi network.

The module served as a web server [15]: it received HTTP requests from clients and sent them HTTP responses containing, among other things, the metrological information needed to calibrate the flow meter [9] presented.

The built-in flash memory of the ESP8266 NodeMcu v3 allows writing HTML/CSS page calibration software [8] and preprocessing functions in the form of JavaScript scripts, text report forms, JSON files, and other informations transmitted over the Internet along with HTTP responses gave. The GET method is used for messaging.

Figure 1 shows the connection diagram of the ESP8266 NodeMcu v3 to the Arduino platform.

In the structural diagram of the calibration of the time-impulse ultrasonic sensor (Fig. 2), the LED lamp connected to pin 9 of the digital output is connected to a resistor with a resistance of 220 ohms to limit the current. The timing pulse sensor is connected to pin Vin and then to pin A0 of the analog output with a 10k resistor as ground.

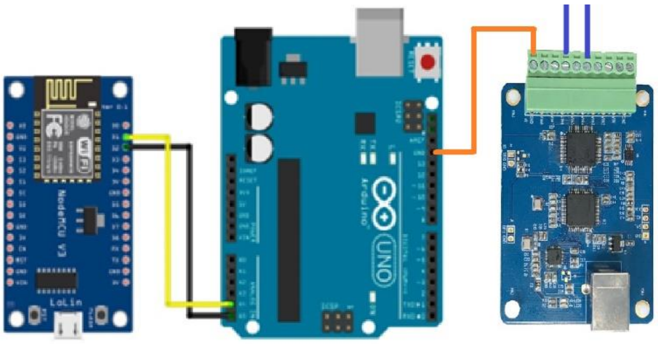

Fig. 1. ***Wiring diagram for Arduino platform ESP8266 NodeMcu v3 and ADC ADS1256.***

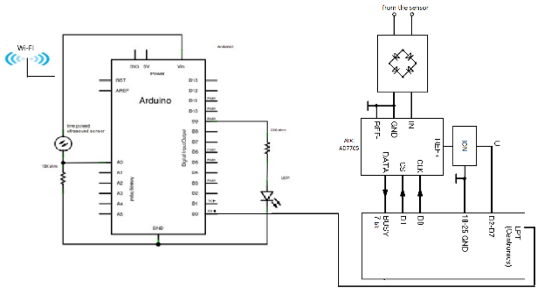

Fig. 2. ***Schematic diagram of the calibration of the time-impulse ultrasound sensor on the Arduino platform.***

To calibrate the measuring instrument, the code is written in the Arduino IDE as follows:

Code:

```
int sensorMin = 1023; // minimum value
int sensorMax = 0; // maximum value
```

They may appear to be inverted values. Initially, the upper limit is set and the lower value is read and stored as the new minimum limit. In addition, the minimum lower limit is set, and the value above it, the new maximum limit is read, for example:

Code:

```
// Calibrate for 5 seconds
 while (millis () < 5000) {
 sensorValue = analogRead (sensorPin);

// set the maximum value
 if (sensorValue > sensorMax) {
 sensorMax = sensorValue;
 }

// set the minimum value
 if (sensorValue < sensorMin) {
 sensorMin = sensorValue;
 }
 }
```

Thus, any subsequent readings can be compared within these minimum and maximum limits:

```
// apply calibration
sensorValue = map (sensorValue, sensorMin, sensorMax, 0, 255);
```

Here is the entire program:

```
/ *
 Calibration
```

The sensor calibration method is shown below:

Scheme:

```
 * analog sensor (time pulse ultrasonic sensor): analog input A0
 * LED: digital pin 9 and connected to ground

http://arduino.cc/en/Tutorial/Calibration

*/
```

```
// These constants do not change:

const int sensorPin = A0; // the pin to which the sensor is connected
const int ledPin = 9; // LED connected pin

// variables:
 int sensorValue = 0; // sensor value
 int sensorMin = 1023; // the minimum value of the sensor
 int sensorMax = 0; // the maximum value of the sensor

void setup () {

 // as an indicator of the start of work, an LED is connected:

 pinMode (13, OUTPUT);
 digitalWrite (13, HIGH);

// Calibrate for 5 seconds
 while (millis () < 5000) {
 sensorValue = analogRead (sensorPin);

// set the maximum value
 if (sensorValue > sensorMax) {
 sensorMax = sensorValue;
 }

// set the minimum value
 if (sensorValue < sensorMin) {
 sensorMin = sensorValue;
 }
 }

// turn off the LED at the end
 digitalWrite (13, LOW);
 }

void loop () {
 // information is read from the sensor:
sensorValue = analogRead (sensorPin);

// apply calibration
 sensorValue = map (sensorValue, sensorMin, sensorMax, 0, 255);

// if the sensor value goes outside the calibration limits
 sensorValue = constrain (sensorValue, 0, 255);

// if the sensor value goes outside the calibration limits
analogWrite (ledPin, sensorValue);
 }
```

The necessary HTML pages of the flow meter calibration interface are written to the ESP8266 NodeMcu v3 flash memory (Figure 1).

A request to the ESP8266 NodeMcu v3 module using AJAX (Asynchronous Javascript and XML) technology, which consists of a "background" exchange of information between the browser and the web server when changes are made to each form field or a button is clicked on the HTML page sent. AJAX is an acronym that stands for Asynchronous Java Script and XML. When using AJAX, there is no need to refresh the entire page every time, because only a certain part of it is updated. This significantly increases the speed of the web application, and in the case of constant informations exchange with devices, it is very difficult to do without AJAX. There are two ways to exchange informations with the server.

The first method is a GET request. In this case (request), the request goes to the document on the server, the arguments are passed to it via the URL address. It is not recommended to send GET requests to a server with large amounts of information. There is a POST request for this.

The client part, written in Javascript, must provide the necessary functionality to securely exchange informations with the server and provide methods for exchanging informations in any of the above ways. The server part must process the input informations and create new informations based on it and return it to the client. For example, to request information from the server, you can use a simple GET request with a few small parameters, but to update the information or add new information, you will need to use a POST request. because it allows you to transfer large amounts of informations.

AJAX uses asynchronous informations transfer. This means that the user can perform other actions while the informations is being transferred.

Conclusions

It is possible to monitor the controlled quantities in a simple system of remote calibration of the water flow measuring devices recommended by us using a personal computer, mobile phone and tablet.

Wi-Fi internet connection worked flawlessly when using ESP8266 NodeMcu v3 module connected to Arduino platform for remote calibration of water flow meters.

The method proposed in the research work significantly simplified the data exchange between the computing device and the flow meter and reduced the cost of software creation due to a unified approach for different operating systems.

When using AJAX (Asynchronous Javascript and XML) technology in the system, there was no need to refresh the entire page every time.

This method of calibration regularly controls the metrological properties of measuring instruments and provides an opportunity to save time compared to other methods of calibration.

References

1. Djalilov, O., Nazarov, E., Sobirov, U., Tasheva, J., Abdunabiyev, S. Urolov, D. (2023). Research of water flow measuring device based on Arduino platform. *Construction Mechanics, Hydraulics and Water Resources Engineering. CONMECHYDRO – 2023. E3S Web of Conferences 401, 04039 (2023).*
2. Djalilov, O., Nazarov, E., Sobirov, I., Gayipov, D., Abdunabiev, S., Urolov D. (2024). Research of ultrasonic sensors for measuring water flow in hydromelioration objects. *IV International Conference on Agricultural Engineering and Green Infrastructure for Sustainable Development. AEGISD-IV 2024.*
3. Pavel Ripka, Alois Tipek (2007). *Modem sensors handbook*. Great Britain: ISTE Ltd, 518 p.
4. Bogush, M.V., Kuzmicheva, E.V., Pikalev, E.J., Bogush, A.M. (2010). Piezoelectric acoustic transducers and ultrasonic gas flow meters based on them. *Automation, telemechanization and communications in the oil industry*. 2, 21-24.
5. Frayden, Dj. (2006). *Modern sensors.* Moscow: Texnosfera. 592 p.
6. Isık, M., Sönmez, Y., Yılmaz, C., Özdemir, V., Yılmaz, E. (2007). Precision irrigation system (PIS) using sensor network technology integrated with IoS/android application. *Appl Sci*, 7(9), 1-14.
7. Abioye, E.A., Abidin, M.S.Z., Mahmud, M.S.A., Buyamin, S., Ishak, M.H.I., Rahman, M.K.I.A. et al. (2020). A review on monitoring and advanced control strategies for precision irrigation. *Comput Electron Agric*, 173, 1-22.
8. Centurelli, F., Monsurro, P., Trifiletti, A. (2010). Behavioral modeling for calibration of pipeline analog-to-digital converters. *IEEE Trans. Circuits and Systems I: Regular Papers*. 1255-1264.
9. Patil, P.L., Desai, B. (2013). Intelligent irrigation control system by employing wireless sensor networks. *Int Jou Comput Appl*, 79(11), 33-40.
10. Rannev, G. i dr. (2007). Informatsionno-izmeritelnaya texnika i elektronika [Information technology and electronics]. M.: Akademiya, 512 p. (in Russian).
11. Kostyukov, A.S., Nikandrov, M.V., Slavutskiy, L.A. (2009). Izmenchivost sluchaynoy pogreshnosti ultrazvukovo`x impulsno`x i doplerovskix izmereniy v neodnorodnoy srede [Variability of random error of pulsed ultrasonic and Doppler measurements in a heterogeneous medium]. *Nelineyno`y mir*. 7(9). 700-705. (in Russian).
12. Velichko, M.A., Gladkix, Yu.P., Satler, O.N. (2017). Ispolzovanie drona v kachestve tochki dostupa Wi-Fi v protsesse sozdaniya energeticheskoy karto` mestnosti [Using a drone as a Wi-Fi hotspot while creating a site energy map]. *Uspexi sovremennoy nauki*. 1(5), 78-80. (in Russian).

13. Gershman, E.M., Pruglo, S.D., Fafurin, A.V., Yavkin, V.B. (2015). Otsenka pogreshnosti izmereniya rasxoda ultrazvukovo`m rasxodomerom v potoke s neodnorodno`m raspredeleniem skorosti zvuka [Estimation of the error of distance measurement by ultrasonic distance in a flow with a non-uniform distribution of sound speed]. *Trudo` Akademenergo.* 3, 7-16. (in Russian).
14. Reva, I.L., Bogdanov, A.A., Malaxova, E.A. (2017). Primenenie tochek dostupa Wi-Fi dlya registratsii dvijeniya na ob'ekte [Using a Wi-Fi access point to record movement at an object]. *Novosibirskiy gosudarstvenno`y texnicheskiy universitet*. 3(68), 104-125. (in Russian).
15. Bankov, D., Khorov, E., Lyakhov, A., Stepanova, E. Fast (2017) Centralized Authentication in WI-FI Halow Networks. *Ieee International Conference on Communications, ICC.* 2017. 1167-1173.
16. Raschella, A., Bouhafs, F., Mackay, M., Shi, Q., Seyedebrahimi, M. (2017). Quality Of Service Oriented Access Point Selection Framework For Large WI-FI Networks. *IEEE Transactions on Network and Service Management*. 14(2). 441-455.
17. Mikhalevskiy, D., Naugolnykh, E., Melnykh, V. (2014). Traffic Transfer In WI-FI Networks While Switching Between Access Points. *Modern scientific research and their practical application*. 21410, 161-165.