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DEVELOPMENT OF A DEVICE AND SOFTWARE COMPLEX FOR ACOUSTIC DIAGNOSTICS OF PROCESSES OCCURRING IN THE SUPERCRITICAL STATE OF A LIQUID AND MONITORING THE WORK OF A MAGNETIC DRIVE UNIT

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There is a problem of studying the processes that occur during the transition of a liquid to a supercritical state and in the process of studying and conducting experiments. There is also a problem of controlling the operation of the electromagnetic device system. Since mechanical, electronic, and other control methods are complicated by the conditions (extremely high pressure, high temperature, location of a part that needs control inside a sealed metal system and is under radiation), an acoustic research method was chosen. As a result of the development, a device based on STM32F407VGT6, DP83848, MAX9814 was created that allows you to receive acoustic data and transmit them over considerable distances using an Ethernet network. Also, applications were developed that enable visualization, storage and processing of acoustic data: a TCP server for data exchange, an operator application that helps to visually control the operation of the magnetic drive and save acoustic data in CSV format, an application for visualization and processing of stored data using methods of statistical and spectral analysis.

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INTRODUCTION

Currently, there is a problem of choosing a coolant for 4th generation reactors, one of the promising ways of development is the choice of a liquid (water) in a supercritical state, unfortunately, this substance has not been studied enough, so the scientific community faces the task of studying water in a supercritical state, as well as all related processes. In this case, a supercritical water convection loop was developed for study, in which the chemical and physical influence of the potential coolant on samples of various substances will be investigated.

There is also the problem of studying the processes that occur during the transition of a liquid to a supercritical state and in the process of studying and conducting experiments. There is also a problem of monitoring the operation of the magnetic drive unit. The article considers the possibility of acoustic diagnostics of a supercritical convection water loop [1, 2] during irradiation with electrons and gamma quanta.

1. STATEMENT OF REQUIREMENTS

In order to meet the needs of the conditions for conducting measurements, additional conditions were also taken into account:

– large number of users;
– the distance of the observers from the place of the experiment is more then 100 m;
– the possibility of recording raw data (for further analysis);
– the need to obtain the spectrum of the received signal.

Thus, it is necessary to get a device that will receive acoustic data at a long distance and transmit it to the user for further analysis, and a software complex that will receive data, store it, distribute it and visualize the necessary indicators.

2. GENERAL DESCRIPTION OF THE DEVICE

Ethernet network was chosen as the main method of communication between devices, as it allows data transmission at distances greater than 100 m and has sufficient bandwidth to transmit the required amount of data.

The decision was made to choose STM32F4-Discovery as the basis for the device, since the microcontroller on this board has a sufficient amount of memory, a fairly high frequency of operation (168 MHz), supports the RMII interface, which allows the use of Ethernet network adapters, and is distinguished by high-precision 12-bit ADC, which allows you to distinguish the signal level with an accuracy of up to 8 mV. The next step was the selection of the microphone module: the MAX9814 has proven itself as a quality microphone module, distinguished by ease of connection and sound registering quality. To work with an Ethernet network was the DP83848 module is selected. The power source is a mobile phone charger that supplies 5 V and 1 A current output.

As a server, you need a computer with the following minimum possible characteristics:

– OS: Windows 7 Professional x64 or Windows 10 Professional x64;
– CPU: dual-core, 2.8 GHz, or better;
– RAM: DDR3 8 GB or better;
– Free space: 10 MB or more.

3. SCHEME OF INTERACTION

The following is chosen as the most appropriate scheme of interaction:

1. The microphone shown in Fig. 1, is connected to the supercritical water convection loop using a metal

rod in order to avoid overheating and ensure better transmission of the acoustic signal.

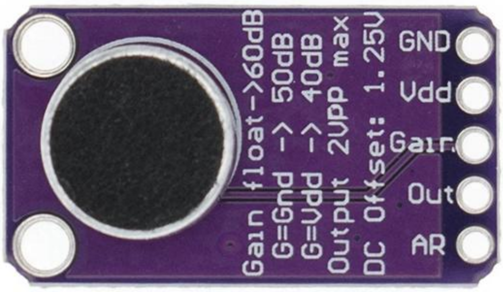

Fig. 1. MAX9814 module

This module is responsible for converting acoustic waves into electromagnetic waves and has the following characteristics:

- Supply voltage: 2.7…5.5 V at a current of 30 mA;
- Output: 2Vpp at 1.25 V offset;
- Frequency response: 20 Hz…20 kHz;
- Programmable attack and decay ratio;
- Temperature range -40…+85 °C.

2. The microphone is connected using a twisted pair to the STM32F4-Discovery microcontroller module represented in Fig. 2. This module is responsible for receiving an analog signal, converting it to a digital one, accumulating data and transferring it to the server application via the Ethernet network. The maximum clock frequency is 168 MHz, the polling frequency of the ADC is 32768 Hz. The supply voltage is 5 V with a current of 300 mA.

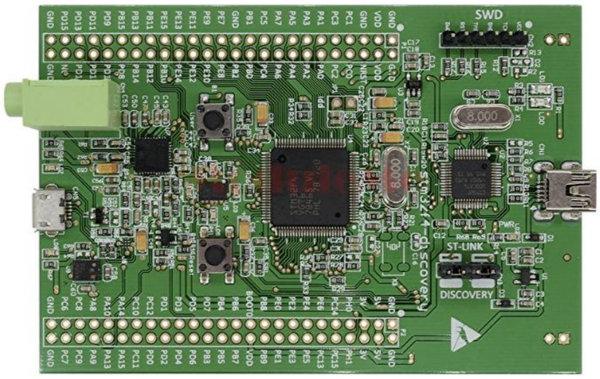

Fig. 2. STM32F4-Discovery module

3. The microcontroller module transmits the recorded data in the form of a TCP packet to the Ethernet adapter board DP83848 shown in Fig. 3 for further data transfer to the server via the Ethernet network.

Fig. 3. DP83848 module

This module is designed for communication of a microcontroller module with an Ethernet network, has the following characteristics:

- Network support: 10/100 Mbit;
- Standard: 802.3u MII/RMII;
- Supply voltage: 3.3 V;
- Consumed power: < 270 mW.

4. The server accepting incoming connections, receives information packets and distributes the accumulated information to all clients, closes the connections.

5. The client who received the information saves the received information in CSV format files at certain intervals. Also, the client performs transformation on the data using the FFT algorithm and displays the received signal spectrum or raw data on the screen. The overall scheme of interaction shown in Fig. 4.

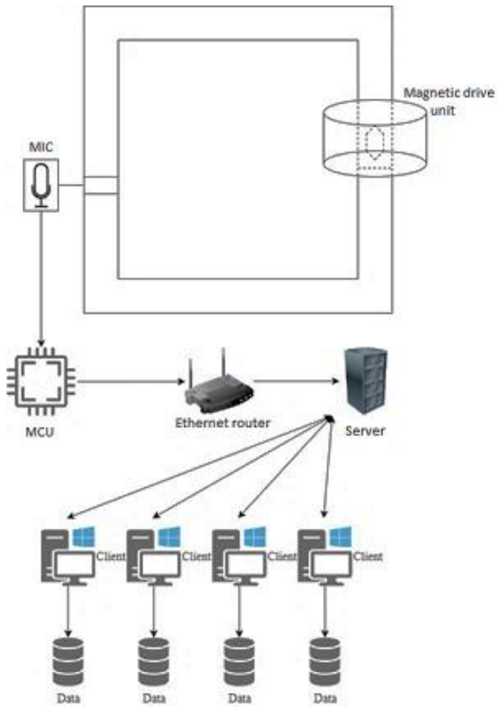

Fig. 4. Device interaction scheme

In this way, the fulfillment of all conditions and tasks is ensured. Users can receive acoustic data at a considerable distance, analyze the operation of the magnetic drive unit using acoustic signal spectrum data.

4. DESCRIPTION OF THE SOFTWARE COMPLEX

A client-server architecture was chosen to fulfill the tasks [3].

Based on the existing material and technical base, applications compatible with the Windows 7/10 OS were developed.

Spectrum! TCP Server

The TCP server takes up 3.7 MB of disk space and is designed to receive data from the microcontroller module and distribute it to clients. The data update period is 1 s. In case of quite active data exchange with clients, the server needs a fairly wide data channel calculated on average of 600 kB/s for each client. The maximum number of connections is set to 500.

Application also displays request flow and IP adresses of connected clients. For better use it can be hidden to the tray, so the new connected clients will be shown as a balloon-popup. The interface of application shown in Fig. 5.

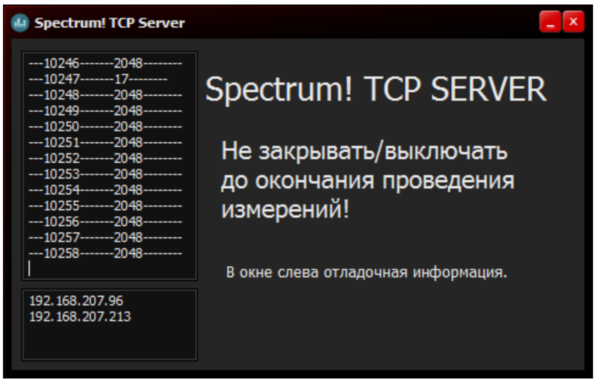

Fig. 5. Spectrum! TCP Server interface

Spectrum!

Client application designed for recording data, visualization of current data. Data is saved in CSV format for easier processing and compatibility with other applications.

The graphic sizes adapt to any monitor sizes and resolutions. Also, the graphic is easily scaled in any area convenient for the user, there is an option to choose a recording period and an instant recording button for urgent recording in emergency situations.

Every second, the application receives 32768 records in the range from 0 to 4096, which corresponds to the amplitude received by the microphone. Next, using the FFT algorithm [4], we get a spectrum that allows us to estimate the spectral pattern of the existing signal from 15 to 16384 Hz (according to the minimum sensitivity threshold of the microphone and the Nyquist frequency). The user can also switch between spectrum and raw data observation modes. The interface of application shown in Fig. 6.

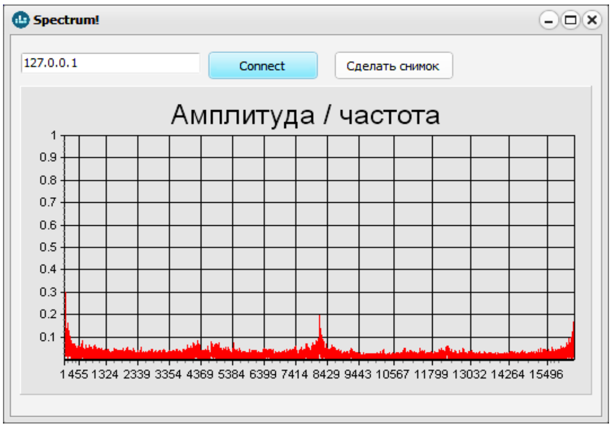

Fig. 6. Spectrum! Interface

Spectrum! ReMember

The application is intended for visualization, conversion and processing of already saved data.

For the application to work, you need to place it in the folder with saved data and run it. This application provides an opportunity to save graphics in full or scaled parts in BMP format. The application can currently be used to compare, find the difference between 2 graphs. Display data both in raw form and in the form of a spectrum using the FFT algorithm.

All the above parts of the complex are fully compatible with operating systems Windows 7/10 Professional x32/x64. The interface of application shown in Fig. 7.

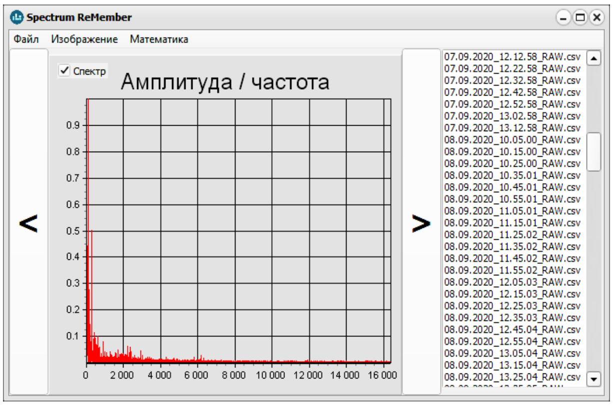

Fig. 7. Spectrum! ReMember interface

Software for STM32F4-Discovery

The STM32F4-Discovery board is equipped with a 12-bit ADC and an RMII interface that allows you to operate the MAX9814 microphone module and the DP83848 Ethernet adapter.

When receiving power, the STM32F4-Discovery board initiates the Ethernet adapter and tries to connect to the server, if the server is unavailable, the indicator turns on – the red LED blinks, if the server is unavailable for too long – the board reboots, which allows to reset all connections and start the initialization from the beginning. If the communication line is not available – the cable is damaged or the cable is missing – the board turns on the red LED and waits for a correct connection. If the connection with the server has taken place and the data is transferred successfully, the board turns on the indication – the green LED flashes.

The time required to continue data transfer after the device is turned off and the power is restored is 2…3 s. In case of critical errors due to network malfunction or incorrect requests from the server or overload in cases of network flooding, the device reboots, resetting connections, makes attempts to reconnect to the server and, if successful, continues to transfer data. Accumulation of the data received by the ADC takes place using two buffers: at first the first one is filled, then it is queued for transmission and transmitted, while the second one is filled. Such a carousel of buffers allows you to transfer data without any data loss [5].

The device also supports hot-swap of the microphone module, which can fail due to excess moisture, radiation, or power surges.

5. DEVICE MODULE CONNECTION DIAGRAM

This device is based on 3 modules: STM32F4-Discovery, DP83848 and MAX9814. The STM32F4-Discovery motherboard is connected to the DP83848 adapter using the RMII interface in the way represented in Fig. 8.

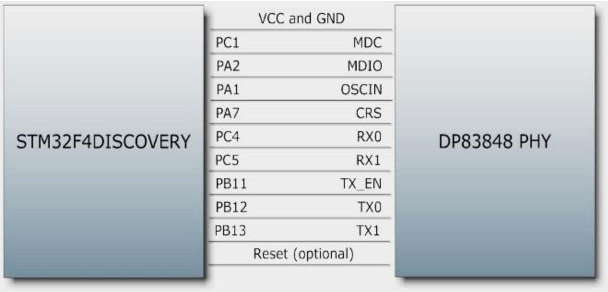

Fig. 8. Connection diagram of STM32F4-Discover and DP83848

The MAX9814 microphone module receives power from the STM32F4-Discovery board and transmits an analog signal to the microcontroller's ADC the connection of modules shown in Fig. 9.

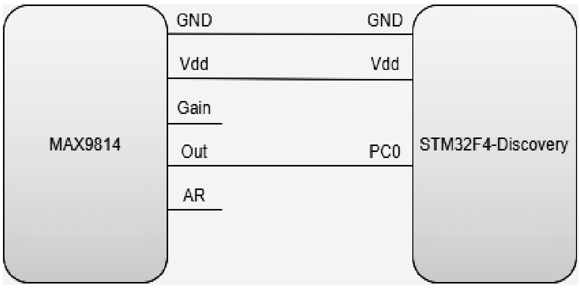

Fig. 9. STM32F4-Discovery and MAX9814 connection diagram

The device has been tested and calibrated before installation. The frequencies of the sound generated corresponded to the frequencies detected by the device.

6. SOME DATA RECEIVED DURING DEVICE OPERATION

During the operation of the device, the raw acoustic data represented in Figs. 10 and 11 was obtained regarding the operation of the magnetic drive.

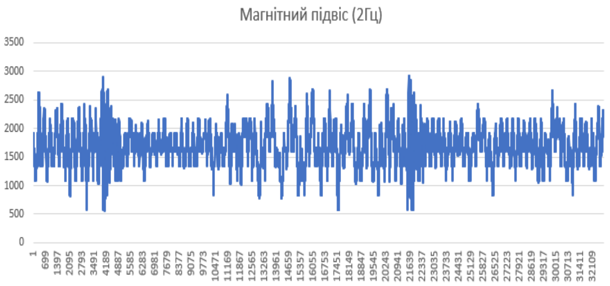

Fig. 10. Illustration of the operation of the magnetic drive at a frequency of 2 Hz

Fig. 11. Illustration of the operation of the magnetic drive at a frequency of 4 Hz

This figures illustrates the presence of drive shocks to a pattern with a frequency of 2 and 4 Hz.

The water and the metal body of the supercritical water convection loop act as conductors of sound waves generated by the impact of the metal drive part to the pattern. In this way, we get 2 sets of sound waves – infrasound waves (depending on the suspension operating frequency of 2, 3 or 4 Hz) and waves generated by beating, which is formed from elastic vibrations of deformed metal. Unfortunately, the infrasound component cannot be distinguished, as for the reflection of a wave from an obstacle, the size of the obstacle must be comparable to the wavelength, it can be concluded that these waves will not be reflected or resonate under the specified conditions, which means that a microphone with a range of 20…20000 Hz will not be able to register it.

The spectral component of the normal operating mode was also obtained. The result of measurement shown on Fig. 12.

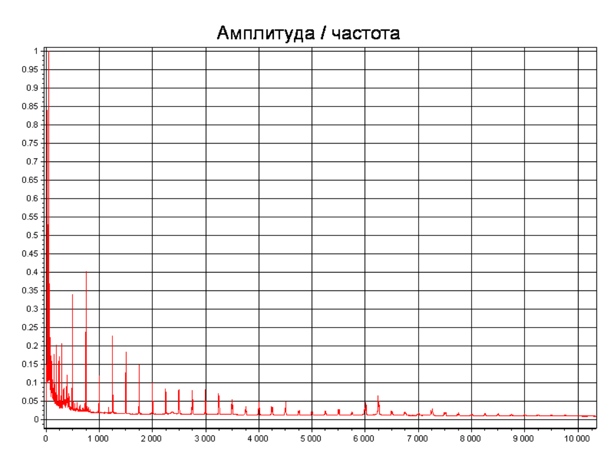

Fig. 12. Pattern of a normal operating mode spectral component

Also all the data obtained during the experiment was stored for future analysis.

CONCLUSIONS

The developed device and software complex completely fulfill the tasks set for obtaining, transmitting, storing, processing and visualizing acoustic data obtained during the experiment.

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РОЗРОБКА ПРИСТРОЮ ТА ПРОГРАМНОГО КОМПЛЕКСУ ДЛЯ АКУСТИЧНОЇ ДІАГНОСТИКИ ПРОЦЕСІВ, ЩО ВІДБУВАЮТЬСЯ В НАДКРИТИЧНОМУ СТАНІ РІДИНИ, ТА КОНТРОЛЮ РОБОТИ МАГНІТНОГО ПРИВОДУ

В.М. Борискін, В.В. Чуріков, В.О. Момот

Постає проблема вивчення процесів, що відбуваються під час переходу рідини у надкритичний стан та при проведенні експериментів. Також існує проблема контролю роботи системи електромагнітного пристрою. Так як механічний, електронний та інші методи контролю ускладнені за умовами (надвисокий тиск, висока температура, знаходження частини, що потребує контролю всередині герметичної металевої системи та знаходиться в умовах опромінення), було обрано акустичний метод дослідження. В результаті розробки було створено пристрій на базі STM32F407VGT6, DP83848, MAX9814, що дозволяє отримувати акустичні дані та передавати їх на значні відстані за допомогою мережі Ethernet. Також були розроблені додатки, що надають змогу візуалізувати, зберігати та опрацьовувати акустичні дані: TCP-сервер для обміну даними, додаток оператора, що допомагає візуально контролювати роботу магнітного приводу та зберігати акустичні дані у форматі CSV, додаток для візуалізації та опрацювання збережених даних з використанням методів статистичного та спектрального аналізів.