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Digital signal processing during measurement of magnetic materials parameters

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Abstract. The principles of digital signal processing in the form of electrical voltage, which contain the information necessary for indirect measurement of magnetic induction, magnetic field strength, magnetic permeability and other parameters of magnetic materials are outlined. The structure of the processor module is presented, which implements the technique for measuring the parameters of magnetic materials and monitors the serviceability of the measuring installation. An interface has been developed that allows remote control of an information-measuring system for measuring the parameters of magnetic materials.

Keywords: magnetic materials, digital processing, magnetic induction, coercive force, measurement, processor module

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Материалы конференции
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Цифровая обработка сигналов в процессе измерения параметров магнитных материалов

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Аннотация. Изложены принципы цифровой обработки сигналов виде электрического напряжения, которые содержат информацию, необходимую для косвенного измерения магнитной индукции, напряженности магнитного поля, магнитной проницаемости и других параметров магнитных материалов. Представлена структура процессорного модуля, который реализует методику измерения параметров магнитных материалов и осуществляет контроль исправности измерительной установки. Разработан интерфейс, позволяющий осуществить дистанционное управление информационно-измерительной системой для измерения параметров магнитных материалов.

Ключевые слова: магнитные материалы, цифровая обработка, магнитная индукция, коэрцитивная сила, измерение, процессорный модуль

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Introduction

Modern electronics is developing towards the widespread use of digital signal processing, which is performed in various ways and methods: using general-purpose microcontrollers, programmable logic integrated circuits (FPGAs), digital controllers (DSP) [1, 2].

Digital signal processing methods are the most effective, as they provide more stable temperature and time parameters and allow changing the coefficients of transfer functions. Digital signal processing methods have less impact on the signal output parameters [3]. This is due to the absence of parasitic parameters inherent in passive components, such as capacitors and resistors, which are one of the components of analog integrator circuits [4].

Integrating circuits are used in various functional units: voltage-frequency converters, frequency-voltage converters, analog-to-digital converters, control units in automatic control systems, pulse generators, active analog filters [5]. As the device operates, it is necessary to change its parameters in the integrating circuit, namely the time constant, that is, to rebuild it. In turn, it is accompanied by transition processes that influence the result of integration [6].

The developed automated information-measuring system (IMS) for studying the parameters of magnetic materials is based on indirect measurements of magnetic induction and coercive force by integrating the secondary winding voltage and magnetizing current, respectively [7].

Materials and Methods

During the development process, it is possible to expand the functionality of the installation due to the modularity of the design. The main functional blocks of the measuring installation are: a standby power supply (provides power to the auxiliary units of the installation, i.e. a board with a microprocessor, operational amplifiers in the measuring channel, a board with a hardware integration module), a switching power supply (generates voltages for the magnetizing winding of the test sample), a processor module, integration module performing numerical integration in hardware (under development).

The processor module is based on an STM32F429 microcontroller. Figure 1 shows the block diagram of the processor module.

The processor module includes: SPI modules for interaction with the TFT display, UART and Ethernet for user interaction, built-in memory controller for data exchange with an external SDRAM chip, an analog-to-digital converter (ADC) using 4 channels, and a digital-to-analog converter (DAC) to set a code proportional to the magnetizing current value. Service and user information is stored in an external EEPROM memory chip. Channel 1 of the ADC is used to diagnose the power supply. Channel 2 receives readings from the current sensor of the current shaper, which sets the magnetic field strength. In channel 3, the EMF proportional to the magnetic induction is measured.

The relationship between electromotive force and magnetic induction B is described by the following expression:

$$B = \frac{\int \varepsilon(t)dt}{S \cdot n_{II}},$$

where S is the cross–sectional area of the core; n_{II} is the number of turns of the magnetizing winding; ε- the electromotive force of the measuring winding, which is converted into a digital code by means of an analog-to-digital converter.

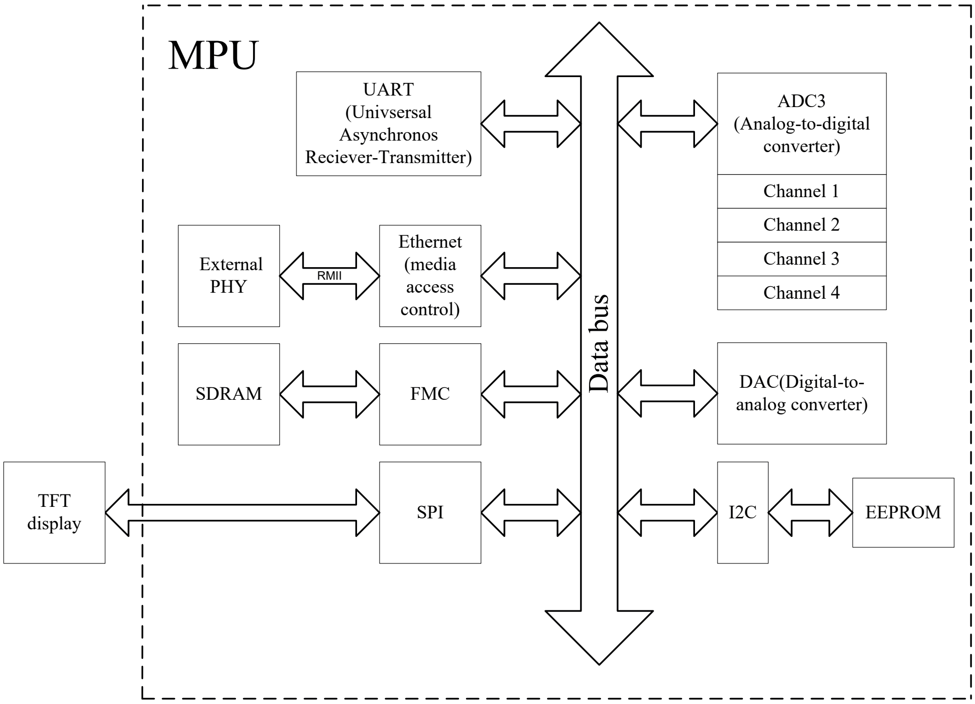

Fig. 1. Structure of the processor module

The use of two interfaces allows to expand the functionality of the installation. Using the RS232 interface, you can configure installation parameters (setting Ethernet network parameters). Thanks to a special client application, measurement results are displayed on the monitor. The disadvantage of this approach is the dependence on the target platform on which the client application must be deployed. The Web Interface does not have this drawback, access to which is provided by the Ethernet interface. For its work, the current version of the web browser must be installed on the client computer. Based on the use of Web Interface, remote work with the measuring installation, which is advisable to use both for educational purposes when performing remote laboratory work, and in scientific research of magnetic materials and structures based on them is organized.

The appearance of the printed circuit board of the processor module is shown in Figures 2 and 3.

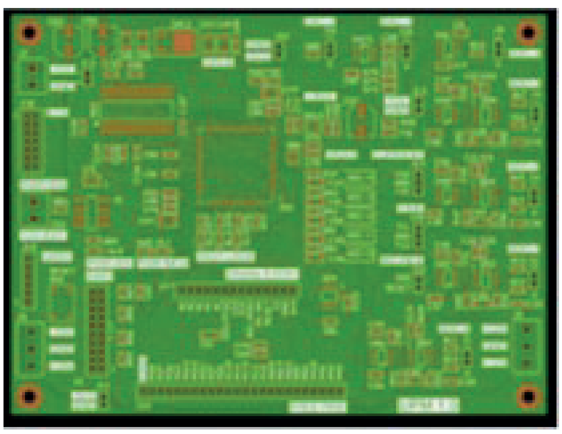

Fig. 2. The printed circuit board of the processor module, top view

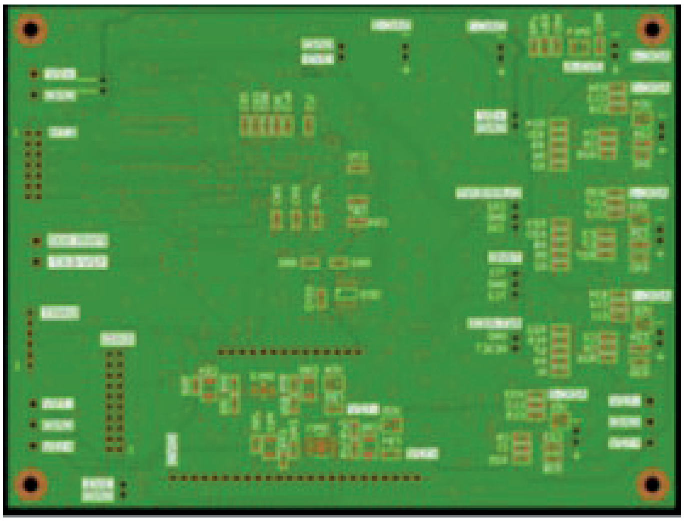

Fig. 3. Printed circuit board of the processor module, bottom view

The control program of the processor module includes a real-time operating system (RTOS). The tasks of the operating system include servicing data transmission via the UART interface, exchanging information with external devices and interacting with the TCP/IP stack necessary for the web interface implementation.

The TCP/IP protocol stack is implemented using the open source lwIP library. The lwIP stack is responsible for data generation, routing, and transmission.

This model includes four levels of abstraction, which are used to sort all related protocols according to the volume of the network used. Figure 4 shows the lwIP model architecture from the lowest to the highest layer:

· The channel layer contains communication technologies for one network segment (channel) of the local network.

· The Internet Layer (IP) connects independent networks, thereby establishing interconnection.

· The transport layer handles data exchange between hosts.

· The application layer contains all protocols for specific data transfer services at the interprocess level.

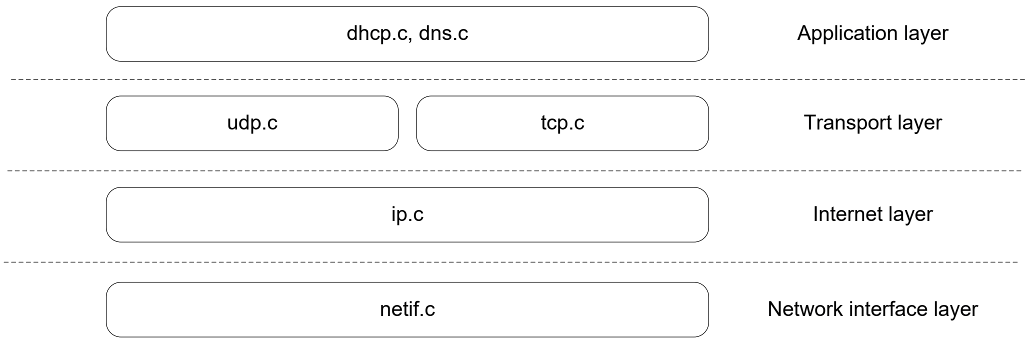

Fig. 4. lwIP Architecture

The firmware of the processor module implements three measurement modes.

The first mode consists in removing the voltage proportional to the magnetic induction from the operational amplifier. In this mode, an analog integrator circuit, which provides high performance is used. It is recommended to use this mode during rapid analysis, which is typical for conducting input control of ferrite products. The measurement error in this case depends on the variation of the operational amplifier parameters, which is reflected in the measurement result.

The second measurement mode is the oscilloscope mode. The voltage measured by an analog-to-digital converter (ADC) is transmitted directly from the measuring winding to the computer.

The third measurement mode uses a digital integrator, which is a separate module. The digital integrator communicates with the processor module via the SPI interface. The digital integrator board has its own ADC, which receives the reference points of the measuring pulse, and a programmable integrated logic circuit (FPGA) implementing a numerical integration method. The values obtained by the FPGA from the ADC are accumulated in the internal structure. Upon completion of the integration process, the FPGA informs the processor module with a strobing bit that it is ready to transmit data, then the read data from the FPGA is transmitted to the computer by the processor module.

Figure 5 shows the appearance of the web interface and the result of the measurements performed in graphical mode.

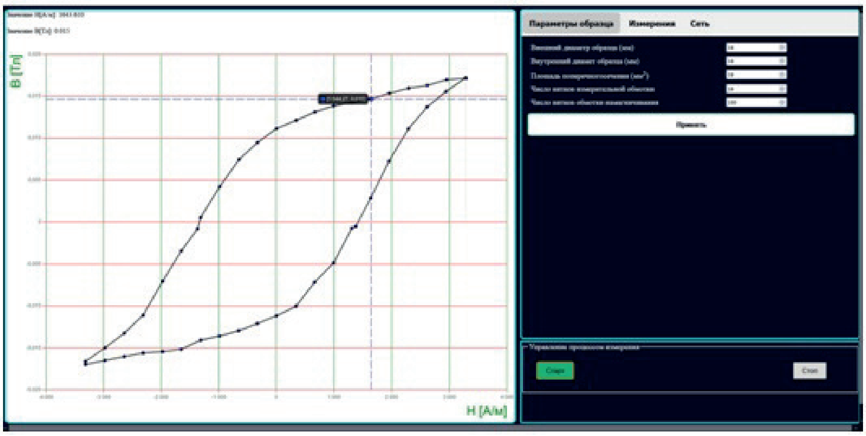

Fig. 5. The interface window with the measurement results performed by the processor module

Conclusion

The presented processor module, which is part of an information and measurement system for studying the parameters of magnetic materials, provides automation of the measurement process of ferrite products. The hardware and software complex allow you to reduce the operational time spent on performing measurement tasks. The number of operations performed by the operator is reduced by at least 3 times compared to non-automated measuring instruments. The presence of two interfaces allows you to increase the system reliability. The UART interface, in addition to measuring tasks, performs the function of a debugging interface that allows you to configure the measuring installation and display the parameters on the computer screen or the installation display. Remote access to the installation is possible via the Ethernet interface and using the web interface. The use of Ethernet technology makes it possible to include the installation in an automated production control circuit.

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