Experimental Module for Contactless Measurement of Electrical Current

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Abstract – **Magnetic field sensors have been widely used in household and engineering practice. Their important advantage is their ability to measure different electrical parameters only by measurement of a magnetic field based on advanced sensors for electric current measurement by a magnetic field.**

A sensing module for measuring electrical current has been developed.

This article presents an experimental measuring module realized on the basis of a magnetosensitive integrated circuit with a Hall element. The block diagram, a general electrical circuit and results of experimental studies are described.

Keywords – **Galvanomagnetic sensors, Current sensors, Electromagnetic sensors, Hall sensors, Electric current measurement.**

I. Introduction

With the development of newer electronics technologies, in particular, sensor technology – Hall effect sensors are becoming increasingly popular in engineering environments as the primary means of measuring electrical current with high reliability, performance, sensitivity and accuracy. They are successfully applied for measurement and control of the parameters of electrical circuits. Today, Hall's components are widely used in almost all measuring device and household appliances in light and heavy industries.

Interest for sensors technologies is the contactless measurement of the parameters of electrical signals and more precisely, of the electrical parameters of power circuits. This method has many advantages the most important among them is the galvanic separation of the two circuits – the measured and measuring [1-10].

There are various sensor transducers that allow contactless measurement of circuitry parameters. They work on different physical principles – optical, inductive, magnetic, galvanomagnetic. The last are widespread in modern electronics and automation. They have some very important advantages over others, namely easy signal processing, repeatability, high sensitivity to broadband frequency signals, reliability, and more [1-6].

The purpose of the present study is to design, develop and study a real-time sensor module for electrical current measurement based on a modern magnetosensitive integrated circuit with a Hall element.

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II. Presentation

The block diagram of the realized module is shown in Figure 1.

The main unit is the magnetosensitive integrated circuit (MIC), which converts the magnetic field into an electrical signal, a voltage stabilizer (VS) providing the required DC mode and an interface circuit (IC) that forms the signal in a suitable form for follow processing.

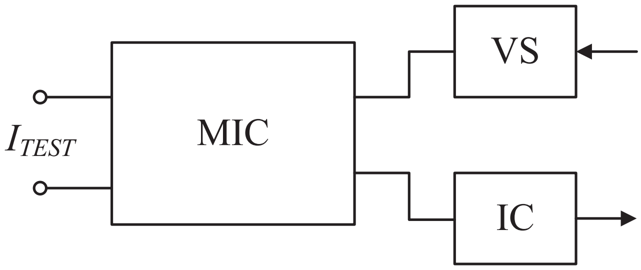

Fig. 1. Block diagram of the measureming module

The developed model is a single-PCB module with detached terminals, connecting the measured circuit to the current terminals of the magneto-sensitive IC. The last is a monolithic silicon chip with a magnetosensitive element and a processing circuit mounted on a current-carrying bus the ends of which are the IP + and IP- current measuring terminals of the integrated circuit. When a current flows through the bus, a magnetic field is formed around it which is detected by the sensor integrated in the package, and it converts the magnetic field into a proportional output voltage.

Figure 2 shows the circuit diagram of the developed module.

The stabilizer block is built with an integral voltage stabilizer of type LM7805 (IC_1). The developed device is of an experimental type. The supply current I_S that is required for it does not exceed 50mA. Of course, when installing the device into portable measurement and battery-powered systems, it is necessary to replace it with an appropriate low dropout voltage regulator.

The magnetosensitive integrated circuit (IC_2) of type ACS710 for electrical measurement with Hall element is produced by Allegro Micro Systems Company [9]. It provides a precise solution to convert the size of alternating and direct current in output voltage. Due to its small dimensions, it can be embedded in the package of most electronic devices for electrical currents measurement in current protections, instantaneous values of electrical signals, control and diagnostics of power transducers and electrical equipment.

In this type of IC, the current terminals (IP + and IP-) must be connected to the measured current loop in a given circuit. Current terminals IP+ and IP- of the integrated circuit have respectively four physical terminals internally integrated into a common copper conductor with R_{IP+IP-}=1mΩ. They provide the carrying out and measurement of electrical current up to 25A. The sensor signal processing scheme allows to measure positive and negative values of electrical current, but it is necessary to observe the polarity of the IP+ and IP- terminals when entering the circuit. The selected magnetosensitive integrated circuit is equipped with Fault and Fault_EN functions. It can provide additional feedback to detect the maximum value of the measured current. This improves the functionality and reliability of the sensor device. The speed of the sensor

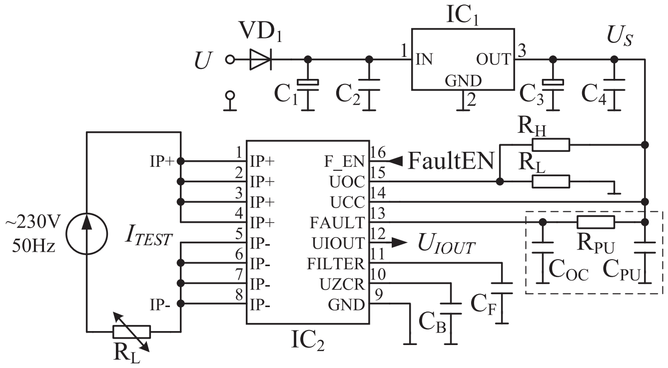

Fig. 2. The circuit diagram of the developed module

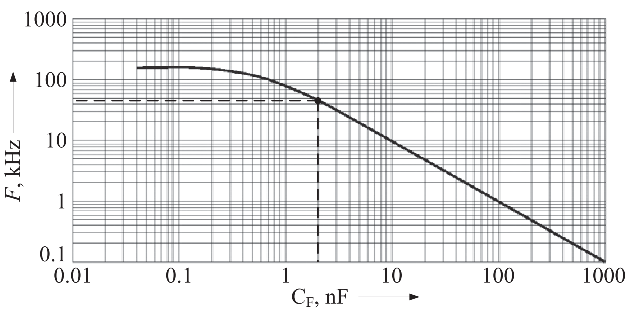

Fig. 3. Dependence of the frequency of operation on the value of the $F = f(C_F)$

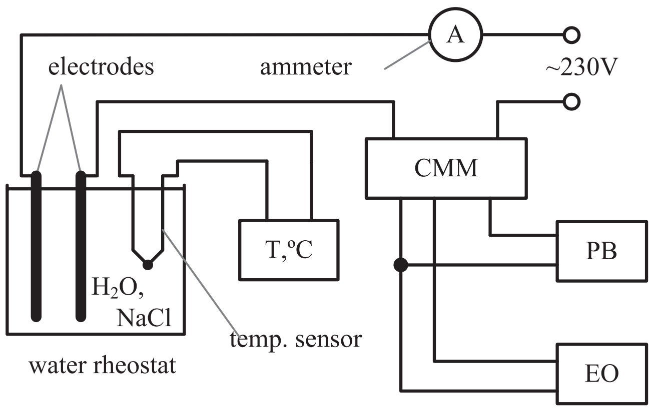

Fig. 4. Schematic diagram of the experimental setup

can be set by selecting a suitable C_F capacitor.

Figure 3 shows the dependence $F=f(C_F)$. It can clearly be seen that at higher capacitance values the operating frequency sharply decreases. Another application of C_F is to adjust the noise steadiness. The low noise steadiness is observed by low capacitance value. So it is necessary when a sensor is used in an apparatus to take into account these two parameters – noise steadiness and speed of work [2]. Figure 3 shows an exemplary selection of the capacitor value C_F limiting the transmit frequency to 45 kHz. This is necessary for further development.

The output of the MIC is at terminal 12 (U_{IOUT}). Its voltage changes in proportion to the magnitude of the measured current I_{TEST}.

The schematic diagram of the experimental setup is shown in figure 4.

A water rheostat with NaCl water solution has been used for

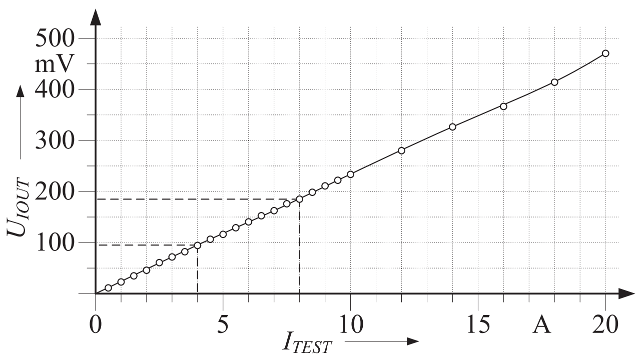

Fig. 5. Experimental transmission characteristic $U_{IOUT} = f\,(I_{TEST})$

carrying out the experimental tests. So it is possible to control fluel the current I_{TEST} through measuring module and contactless ammeter.

For the purpose of collecting data for further studies the temperature of the magnetosensitive integrated circuit package T_P and that of the water rheostat T_W solution are also measured. Output data are measured by a two channel electronic oscilloscope (EO).

The obtained experimental transmission characteristics are shown in Figure 5.

They reflect the variation of the output voltage U_{IOUT} from the set current I_{TEST} passing through the sensor module. The analysis of the results shows that the transmission characteristic is linear across the current range (I_{TEST}=0÷20A). From the obtained results the absolute sensitivity S_A of the developed device is determined. It is given by the following formula:

$$S_A = \frac{\Delta U_{IOUT}}{\Delta I_{TEST}} \qquad (1)$$

where: ΔU_{IOUT} – change of the output voltage from the magnetosensitive integrated circuit; ΔI_{TEST} – the change of the set current, or:

$$S_A = \frac{90{,}7}{4} = 22{,}66 mV / A \qquad (2)$$

From the calculations for the S_A it is found that the absolute sensitivity of the test module was kept constant

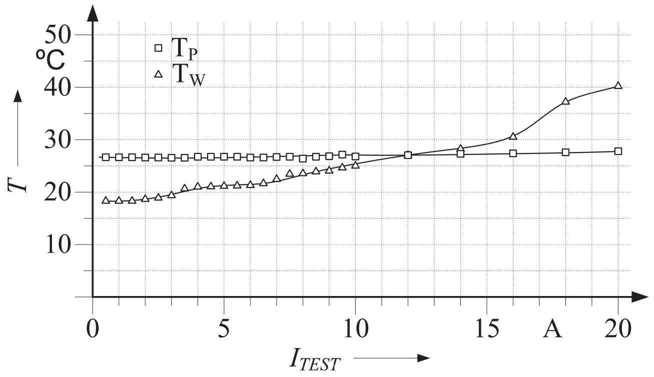

Fig. 6. Graphic dependencies $T_P = f\,(I_{TEST})$ and $T_W = f\,(I_{TEST})$

S_A=22,66mV/A. For additional information which can help the used module modeling are obtained the characteristics $T_W = f\,(I_{TEST})$ and T_P=$f(I_{TEST})$. They reflect respectively the water temperature of the water rheostat and that of the magnetosensitive integrated circuit package. The temperature of the chip has a minimal change over the entire operating range, due to the very low resistance of the built-in low resistive copper conductor. The dependencies are presented in the general graph of Fig. 6.

III. Conclusion

Sensor module with modern magnetic-sensitive integrated circuit with a Hall element of type ACS710 produced by Allegro Microsystems Company it is developed.

Magnetic-sensitive elements are becoming more widely used. The development of new sensor components on their basis extends the functional capabilities of the device in which they are built.

The developed measuring module is characterized by easy and inexpensive craftsmanship. The use of a magnetic-sensitive integrated circuit allows to measure electrical signals with a wide range of variation of the parameters, such as amplitude, frequency, rise time, and others.

Block diagram of the device consisting of a integrated sensor and power supply circuit is given.

A electrical circuit diagram of a module for measuring electrical current is synthesized, realized and studied.

With simple schematic solutions the overvoltage protection of the supply voltage poles is greater than the supply voltage (U_S = 5 ÷ 15V).

The sensor used in the module enables of bi-directional measurement of direct and alternating currents up to I_{TMAX} = ±25A.

The module possibility of feedback realizing when maximum current is reached through external pins of integrated circuit.

Low self-consumption power consumption of the module (I_S<50mA), both in measurement mode and standby mode, and the small dimensions allow him to be built integrated in various electronic devices where it is necessary to measure and monitor the magnitude of the electrical current.

The capability of the conversion feature of the module enables the output electrical signal to be directly coupled to the ADC input thereby simplifying its processing. It is determined absolute sensitivity. It is S_A = 22,66mV/A.

An experimental set-up was realized (Figure 4). The water rheostat configuration allows the measurement of the electrical current flowing through the sensor to be readily measured.

Experimental studies have been carried out and have been reflect the measuring module work.

Transformation characteristics $U_{IOUT} = f\,(I_{TEST})$ and these reflecting temperature regimes during operation T_P= $f\,(I_{TEST})$, T_W= $f\,(I_{TEST})$ at different values of the measured current I_{TEST} = 0,1 ÷ 20A are built in sequence.

Developed and tested device is intended for installation in a variety of instrumentation and devices allowing its output signal to be used to measure and build feedbacks monitoring of various electrical parameters of the power circuits.

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