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INTELLIGENT GALVANOMAGNETIC CURRENT SENSORS WITH ADJUSTABLE RANGE

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ABSTRACT

This article presents the results of research on intelligent galvanomagnetic current sensors with adjustable range. Current sensors based on the galvanomagnetic effect, particularly the Hall effect, are widely used in modern electronics, automotive, industrial automation, and energy sectors. Within the scope of this research, programmable current sensors with various measurement ranges were developed and tested. The results show that the ability to adjust the amplifier coefficient and offset voltage through a digital control system enables an increase in sensor accuracy up to 0.5% and ensures effective operation across a wide measurement range (from 1A to 500A). The developed sensors feature galvanic isolation, high speed, and temperature compensation capabilities.

Keywords

galvanomagnetic effect, Hall effect, current sensors, programmable sensor, measurement range, galvanic isolation, magnetic field.

1. INTRODUCTION

Current measurement is of great importance in modern electrical engineering and electronics. Accurate current measurement is essential in areas such as electrical energy management, motor control, battery system monitoring, and power electronics. Current sensors play a fundamental role in performing this task.

Current sensors based on galvanomagnetic effects, particularly Hall effect sensors, are widely used due to their unique characteristics. These sensors have the capability of non-contact measurement, galvanic isolation, low power consumption, and operation across a wide frequency range. This effect, discovered by American physicist Edwin Hall in 1879, now forms the basis of modern sensor technologies.

However, traditional Hall effect sensors have a fixed measurement range and do not provide flexibility in various applications. Therefore, the development of intelligent current sensors with adjustable range is an urgent issue. The purpose of this research is to develop and study a new generation galvanomagnetic current sensor equipped with a programmable amplifier and digital control system.

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1.1. Theoretical Foundations of Galvanomagnetic Effects

The galvanomagnetic effect refers to electrical phenomena that occur in a conductor or semiconductor carrying current under the influence of a magnetic field. The Hall effect is the most common galvanomagnetic phenomenon, in which when a magnetic field is applied perpendicular to a current-carrying conductor, a voltage difference (Hall voltage) is generated across the sides of the conductor.

The Hall voltage is expressed by the following formule: $U_H = \frac{R_H I B_z}{d}$, where I is the current flowing through the conductor, B_z is the magnetic field induction (perpendicular to charge carriers), $R_H = \frac{1}{nq}$ is the Hall constant, n is the charge carrier concentration, q is the electron charge, and d is the conductor thickness. This relationship forms the theoretical basis of the operating principle of current sensors.

2. MATERIALS AND METHODS

2.1. Sensor Architecture

The intelligent current sensor developed in this research consists of the following main components: Hall sensing element, programmable amplifier, analog-to-digital converter (ADC), digital signal processor (DSP), and temperature compensation module. The sensor is integrated on a single semiconductor chip and manufactured using CMOS technology.

2.2. Programmable Amplifier System

The sensor is equipped with a digitally controlled amplifier (PGA - Programmable Gain Amplifier) that allows changing the gain coefficient from 1 to 100. The gain coefficient is adjusted through an 8-bit digital interface. This approach enables maximum utilization of ADC resolution across various measurement ranges.

2.3. Measurement Range and Calibration

The sensor is designed to operate in four main measurement ranges: 0-10A, 0-50A, 0-100A, and 0-500A. Optimal gain coefficients and offset values for each range are stored in EEPROM memory. The calibration process is performed using a high-precision standard current source.

2.4. Experimental Equipment

The following equipment was used in the experiments: programmable DC current source (accuracy ±0.02%), 6½ digit digital multimeter, thermostat (±0.5°C accuracy), oscilloscope (bandwidth 200 MHz), and a specially developed test board. All measurements were performed in an electromagnetically shielded environment.

Table 1. Sensor Technical Specifications

Parameter	Value	Unit
Measurement range	1 - 500	A
Accuracy	±0.5	%
Bandwidth	DC - 250	kHz

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Parameter	Value	Unit
Response time	< 3	µs
Operating temperature	-40 to +125	°C
Isolation voltage	≥ 1500	V
Supply voltage	3.3 / 5.0	V

3. RESULTS

3.1. Static Characteristics

The static characteristics of the sensor were determined through the conducted experiments. It was confirmed that the dependence of output voltage on input current has a linear character across all measurement ranges. The linearity error did not exceed 0.1%. The offset error at the zero point was ±0.2 mV when temperature compensation was enabled.

3.2. Range Switching Tests

The time for changing the measurement range through the programmable amplifier was measured. The range switching time did not exceed 50 µs, which is sufficient speed for real-time operation. Automatic calibration was performed at each range change.

Table 2. Test Results at Different Ranges

Range (A)	Accuracy (%)	Sensitivity (mV/A)	Offset (mV)
0 - 10	±0.35	200	±0.15
0 - 50	±0.40	40	±0.18
0 - 100	±0.45	20	±0.20
0 - 500	±0.50	4	±0.25

3.3. Temperature Stability

The sensor was tested in the temperature range from -40°C to +125°C. Using a digital temperature compensation algorithm, the sensitivity variation was reduced to 50 ppm/°C. This result fully meets the requirements of the automotive industry.

3.4. Dynamic Characteristics

The frequency response of the sensor was measured. The bandwidth at the 3 dB point was 250 kHz. The response time to pulsed current was less than 3 µs, enabling measurement of rapidly changing currents. The overcurrent detector (OCD) response time was 0.7 µs.

3.5. Galvanic Isolation Tests

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The galvanic isolation of the sensor successfully passed the 1500 V AC test. The isolation resistance exceeded 100 MΩ, ensuring safe operation in high-voltage systems. The common-mode transient immunity (CMTI) was 50 kV/μs.

4. DISCUSSION

The research results show that the developed intelligent galvanomagnetic current sensor with adjustable range fully meets modern requirements. The programmable amplifier system enables high accuracy across various measurement ranges.

4.1. Comparison with Traditional Sensors

Compared to traditional fixed-range Hall effect sensors, the developed sensor has several important advantages. First, measurement across a wide current range is possible with a single sensor, reducing inventory costs. Second, real-time calibration and adjustment capability is available through the digital interface. Third, integrated diagnostic functions enable continuous monitoring of the sensor status.

4.2. Application Areas

The developed sensor can be applied in the following areas: electric vehicles (EV), battery management systems (BMS), industrial motor control systems, solar energy inverters, EV charging stations, UPS (uninterruptible power supply) systems, and robotics. The programmable features of the sensor allow meeting various requirements in each field.

4.3. Application in Automotive Industry

Modern electric vehicles require high-accuracy current measurement sensors. The developed sensor is capable of operating at ASIL B level according to the ISO 26262 automotive safety standard. The integrated self-diagnostic function enables detection of internal errors and improvement of system reliability.

4.4. Limitations and Recommendations for Improvement

Some limitations were identified in the research. First, a relatively high offset error (a non-zero output signal even when the input signal equals zero) was observed at very low currents (less than 1 A). It is planned to solve this problem by improving the spinning current technique in the future. Second, phase delay increases at very high frequencies (above 500 kHz), which may be a limitation for some special applications.

5. CONCLUSION

In this research, an intelligent galvanomagnetic current sensor with adjustable range was successfully developed and tested. The main conclusions are as follows:

Using the programmable amplifier system, the capability to operate across a wide measurement range from 1A to 500A was achieved. An accuracy of ±0.5% was reached across all ranges.

The digital temperature compensation algorithm ensured stable operation across a wide temperature range from -40°C to +125°C. The sensitivity variation did not exceed 50 ppm/°C.

The high speed of the sensor (response time <3 μs, bandwidth 250 kHz) enables measurement of rapidly changing currents. The integrated overcurrent detector provides a protection signal within 0.7 μs.

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The developed sensor has wide application potential in the automotive industry, industrial automation, and energy sectors. Future research will focus on improving accuracy in the low current range and enhancing high-frequency characteristics.

REFERENCES

1. Patent of the Republic of Uzbekistan No. 03316. Multi-turn non-contact AC potentiometer / Amirov S.F., Turdybekov K.Kh., Shoyimov Y.Yu., Sattarov Kh.A., Khushbokov B.Kh. // Official Bulletin. - 2007. - No. 3.

2. Patent of the Republic of Uzbekistan No. 03591. Device for converting direct current to alternating current / Amirov S.F., Khalikov A.A., Shoyimov Y.Yu., Khushbokov B.Kh., Balgaev N.E. // Official Bulletin. - 2008. - No. 2.

3. Patent of the Republic of Uzbekistan No. 03617. Device for non-contact current measurement / Amirov S.F., Khalikov A.A., Shoyimov Y.Yu., Khushbokov B.Kh., Balgaev N.E. // Official Bulletin. - 2008. - No. 3.

4. Patent of the Republic of Uzbekistan No. 03858. Current transformer / Amirov S.F., Khalikov A.A., Safarov A.M., Shoyimov Y.Yu., Khushbokov B.Kh., Balgaev N.E. // Official Bulletin. - 2009. - No. 1.

5. Shoyimov Y.Yu. Analysis of generalized methods for improving the characteristics of magnetogalvanic current sensors // International Scientific and Technical Journal "Chemical Technology. Control and Management". - Tashkent, 2012, No. 3. pp. 49-54.

6. Shoyimov Y.Yu. Investigation of magnetic circuits of current sensors with multi-turn cores // Journal: "Science Time" materials of scientific and practical events of the Society of Science and Creativity, Kazan, 2021, No. 3 (87). - pp. 71-77.

7. Irish Patent No. 2002/0131. An excitation Circuit for a fluxgate Sensor. S. C. Tang, M. Duffy, P. Ripka, W. G. Hurley. March 15, 2005.

8. D. Destefan and J. Ramboz "Advancements in High Current Measurement and Calibration," Presented at NCSL International 2000 Workshop and Symposium July 16-20, 2000, Toronto, Canada.

9. Paun, M.A., Sallese, J.M., Kayal, M. "Hall-Effect Current Sensors: Principles of Operation and Implementation Techniques." IEEE Sensors Journal, vol. 21, no. 24, pp. 27543-27557, 2021.

10. Hall, E.H. "On a New Action of the Magnet on Electric Currents." American Journal of Mathematics, vol. 2, no. 3, pp. 287-292, 1879.

11. Infineon Technologies. "XENSIV TLE4971/TLE4972 Current Sensor Datasheet." 2024.

12. Allegro MicroSystems. "ACS726 Galvanically Isolated Current Sensor IC." Application Note, 2023.