DOI: 10.37102/1992-4429_2026_57_03_09

INVESTIGATION OF A FLUXGATE SENSOR FOR DETECTION OF MAGNETIC ANOMALIES

V.S. Bezkorovainyi, A.N. Kireev, I.V. Miroshnichenko, A.V. Dobrydnev

This paper presents the results of research on fluxgate sensors, which are widely used in underwater navigation systems, magnetic anomaly detection, seabed magnetic surveying, as well as in tasks related to the detection of sunken objects and exploration of underwater mineral deposits. The relevance of this work is driven by the requirements for high speed, energy efficiency, and accuracy of equipment operating under complex hydrological conditions.

Within the framework of this study, a mathematical model describing the formation of the output signal of a fluxgate sensor under unipolar pulsed excitation was examined under field conditions. The relationship between the time to reach the maximum output signal and the magnitude of the excitation signal was established using fluxgate sensor samples with cores made of the amorphous alloy AMAG-170. The experimental procedure included recording sensor output signals with a digital oscilloscope while varying the amplitude of the unipolar excitation pulse within the range of 4–14 V at a fixed pulse duration of 1 μs.

The practical significance of the obtained results lies in the potential for optimizing the operating modes of fluxgate sensors. By knowing the predicted time to reach the maximum output signal for a given excitation amplitude, it becomes possible to synchronize the sensor polling instant with the peak of the useful signal. This approach enables high-speed operation of fluxgate sensors through the use of unipolar pulsed excitation, exclusion of non-informative signal components (reverse overshoot, noise) from processing, reduction of computational load on signal processing systems, and, consequently, a decrease in the critically important power consumption of autonomous underwater vehicles.

Keywords: fluxgate sensor, sensor, underwater research, magnetic anomaly detection, unipolar pulsed excitation, signal amplitude, time to peak formation, magnetic metal detector

References

1. Rosenblat, M. A. Magnetic elements of automation and computing technology / M. A. Rosenblat. 2nd ed., revised. Moscow: Nauka, 1974. 768 p.

2. Dolmatova O.A. Hall sensor, fluxgate, and magnetoresistive sensor: comparative analysis and application areas / O.A. Dolmatova, T.P. Zakirov // Student Spring - 2025: Collection of scientific papers of the 79th Regional Scientific and Technical Conference of Students, Postgraduates and Young Scientists, St. Petersburg, May 13 15, 2025. St. Petersburg: St. Petersburg State University of Telecommunications named after Prof. M. A. Bonch-Bruevich, 2025. P. 95 100. EDN GSVBMR.

3. Ripka P. Review of fluxgate sensors / P. Ripka // Sensors and Actuators A: Physical. 1992. Vol. 33, No. 3. P. 129-141. DOI: 10.1016/0924-4247(92)80159-Z.

4. Ripka P. Advances in fluxgate sensors / P. Ripka // Sensors and Actuators A: Physical. 2003. Vol. 106–107. P. 8–14. DOI: 10.1016/S0924-4247(03)00148-4.

5. The Cluster Mission: ESA's Spacefleet to the Magnetosphere // ESA Special Publications. 2000. Vol. 450. P. 1–20.

6. Zhang T.L. The fluxgate magnetometer for the Venus Express Mission / T.L. Zhang, G. Berghofer, W. Magnes [et al.] // ESA SP-1295. Noordwyk: ESA, 2008.

7. Babcock E.P. CubeSat Attitude Determination via Kalman Filtering of Magnetometer and Solar Cell Data / E. P. Babcock, T. Bretl // 25th Annual AIAA/USU Conference on Small Satellites. Utah, 2011. URL: https://digitalcommons.usu.edu/smallsat/2011/all2011/56/.

8. Heyner D. The BepiColombo Planetary Magnetometer MPO-MAG: What Can We Learn from the Hermean Magnetic Field? / D. Heyner, H. U. Auster, K. H. Glassmeier [et al.] // Space Science Reviews. 2021. Vol. 217. No. 4. Art. 52. DOI: 10.1007/s11214-021-00822-x.

9. Magnetic field experiment for Voyagers 1 and 2 / K. W. Behannon, M.H. Acuña, L.F. Burlaga [et al.] // Space Science Reviews. 1977. Vol. 21. No. 2. P. 235–257.

10. Braverman V.Ya. Analysis of dynamic characteristics of a fluxgate sensor for the joint of welded parts / V.Ya. Braverman, V.S. Belozertsev // Vestnik of Siberian State Aerospace University. 2009. Iss. 25. No. 2.

11. Mukhametshin A.M. Monitoring the state and modes of mining technology installations and processes of mining production based on the application of a geoinformation MMM-system / A.M. Mukhametshin, A. N. Ignatenko // Mining Information and Analytical Bulletin. 2013.

12. Ivanenko A.N. Determination of the spatial position of underwater pipelines using a full-gradient magnetometric system / A.N. Ivanenko, V.V. Arkhipov, V.A. Sapunov // Scientific and Technical Collection. Vesti of Gas Science. 2018. No. 4(36). P. 94–104. EDN YYTDSX.

13. Maslennikov R.O. Test bench for magnetocardiography based on fluxgate sensors / R.O. Maslennikov, A.V. Suchkov, I.A. Yurasov // Izvestiya RAN. Seriya Fizicheskaya. 2020. Vol. 84. No. 11. P. 1519–1523.

14. A new level of magnetocardiography: the use of fluxgates as a sensing element / Belarusian National Technical University. URL: https://rep.bntu.by/handle/data/162657.

15. Coy L. Underwater UXO detection using magnetometry on hovering AUVs / L. Coy [et al.] // Journal of Field Robotics. 2023. Vol. 40, Iss. 4. P. 1045–1067. DOI: 10.1002/rob.22159.

16. Martins A. UX-1 system design – A robotic system for underwater mining exploration / A. Martins, J.M. Almeida, C. Almeida [et al.] // 2018 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS): conference proceedings. Madrid, Spain, 2018. DOI: 10.1109/IROS.2018.8593999.

17. Gusarov A.V. Magnetic survey in the Fanagoria water area / A.V. Gusarov // Archaeology and Geophysics: New Methods and Technologies: proceedings of the international conference. Moscow, 2014. P. 45–48.

18. Artifacts from the bottom: the most amazing finds of the Center for Underwater Research of the Russian Geographical Society / Russian Geographical Society. URL: https://www.vokrugsveta.ru/history/artefakty-so-dna-samye-udivitelnye-nakhodki-centra-podvodnykh-issledovaniy-rgo-id6562181.

19. Marine towed fluxgate magnetometer-gradiometer MFMG-1: technical description and operation manual. Moscow: Spektr-Geophyzika LLC, 2009. 15 p.

20. "TRITON" multichannel magnetometric complex [Electronic resource]. https://granat-e.ru/triton_mag-multichannel.html.

21. Sankov O.V. Investigation of fluxgate sensors of magnetic objects for near-field location systems / O. V. Sankov, V. N. Legkiy // Vestnik of Bauman Moscow State Technical University. Series: Mechanical Engineering. 2009. No. 2 (75). P. 90–101. EDN: KPNNXP.

22. Uchupi E. Resting in pieces / E. Uchupi, R. D. Ballard, W. N. Lange // Oceanus. 1988. Vol. 31. No. 4. P. 53–60.

23. Wessex Archaeology. Wrecks on the Seabed: Assessment, Evaluation and Recording. Geophysical Survey of Designated Historic Wrecks including Mary Rose, A1 Submarine, Hazardous and Invincible: [report] / Wessex Archaeology; commissioned by English Heritage; supported by Aggregate Levy Sustainability Fund (ALSF). Salisbury: Wessex Archaeology, 2003. Survey dates: 11–26 June 2003.

24. Afanasyev Yu. V. Fluxgates / Yu. V. Afanasyev. Leningrad: Energiya, 1969. 168 p.

25. Bezkorovainyi V.S. Development of a mathematical model for the output signal formation of a fluxgate under unipolar pulse excitation / V. S. Bezkorovainyi, Yu. V. Livtsov, V. V. Yakovenko, N. A. Shatova // Vestnik of Ryazan State Radio Engineering University. 2019. No. 70. P. 190–197.

26. Bezkorovainyi V.S. Transfer function of a fluxgate with unipolar pulse excitation / V.S. Bezkorovainyi, O.V. Tarasenko, V.V. Yakovenko, A.A. Ivzhenko // Vestnik of Luhansk National University named after V. Dahl. 2018. No. 4 (10). P. 159–166.

27. Bezkorovainyi V.S. Methods for approximating the magnetization curve of fluxgate cores under unipolar pulse excitation / V.S. Bezkorovainyi, V.V. Yakovenko, S.N. Shvets // Izvestiya of Tula State University. Technical Sciences. 2021. No. 5. P. 25–33. DOI: 10.24412/2071-6168-2021-5-25-33. EDN: TGUUXZ.

28. Polovinka O.D. Effect of active-capacitive load on the transfer function of a fluxgate / O.D. Polovinka, V.S. Bezkorovainyi // Physical Fundamentals of Instrument Engineering. 2025. Vol. 14. No. 1 (55). P. 50–56.

Information about authors

BEZKOROVAINYI Vladimir Sergeevich, Candidate of Technical Sciences (Ph.D. equivalent), Associate Professor, Head, Leading Researcher
Youth Scientific Research Laboratory "Progress"
Federal State Budgetary Educational Institution of Higher Education "Lugansk State University named after Vladimir Dal"
Address: 291034, Lugansk, Molodezhny Quarter, Bldg. 20A
Research interests: Research, development, and application of electromagnetic sensors for monitoring and diagnostic systems of robotic machines and mechanisms
Tel. +7 (959) 529-13-11
E-mail: bezkorvs@mail.ru
ORCID: 0000-0002-8337-7318
SPIN-code: 9833-5114
Author ID: 1220764

KIREEV Andrey Nikolaevich, Doctor of Technical Sciences (Dr. Sci./D.Sc. equivalent), Chief Researcher, Professor, Vice-Rector for Research and Innovation
Federal State Budgetary Educational Institution of Higher Education "Lugansk State University named after Vladimir Dal"
Address: 291034, Lugansk, Molodezhny Quarter, Bldg. 20A
Research interests: Non-destructive testing, ultrasonic diagnostics, and robotics of machines and mechanisms
E-mail: lifter_23@mail.ru
Phone: +7 (959) 136-70-02
ORCID: 0000-0002-7548-3348
SPIN-code: 3172-8780
Author ID: 945387

MIROSHNICHENKO Ivan Vasilievich, Junior Researcher
Youth Scientific Research Laboratory "Progress"
Federal State Budgetary Educational Institution of Higher Education "Lugansk State University named after Vladimir Dal"
Address: 291034, Lugansk, Molodezhny Quarter, Bldg. 20A
Research interests: Research, development, and application of electromagnetic sensors for monitoring and diagnostic systems of robotic machines and mechanisms
E-mail: sensor-3000@mail.ru
Phone: +7 (959) 105-88-65
SPIN-code: 5724-9314
Author ID: 1328613

DOBRYDNEV Alexey Vitalievich, Junior Researcher
Youth Scientific Research Laboratory "Progress"
Federal State Budgetary Educational Institution of Higher Education "Lugansk State University named after Vladimir Dal"
Address: 291034, Lugansk, Molodezhny Quarter, Bldg. 20A
Research interests: Research, development, and application of electromagnetic sensors for monitoring and diagnostic systems of robotic machines and mechanisms
E-mail: mushroomrace@yandex.ru
Phone: +7 (959) 113-07-08
SPIN-code: 4805-3967
Author ID: 1264623

Recommended citation:

Bezkorovainyi V.S., Kireev A.N., Miroshnichenko I.V., Dobrydnev A.V. INVESTIGATION OF A FLUXGATE SENSOR FOR DETECTION OF MAGNETIC ANOMALIES. UNDERWATER INVESTIGATIONS AND ROBOTICS. 2026. No. 3 (57). C. 76–83. DOI: 10.37102/1992-4429_2026_57_03_09. EDN: LQISAY.