© 2019 HSci. ISBN 978-989-8798-06-0

Study of the Magnetic Field Current-Carrying Conductor of Various Geometric Shapes

A Andreev, O Andreeva, K Minakova
National Technical University «Kharkiv Polytechnic Institute», Kharkiv, Ukraine
andreievom@gmail.com

Abstract. The article presents a detailed description of an available compact measuring complex for studying the magnetic field of conductors with different currents based on the ATmega 328 microcontroller.

The conductor is fixed on the tablet (horizontal surface with a hole system containing a digital magnetic field sensor) with a thermoplastic adhesive. This makes it possible to investigate the magnetic field of not only closed circuits with a current of various geometric shapes, but also individual sections of the conductor. The use of a microcontroller allows to reduce the error of the obtained experimental results by automated repeated repetition of measurements and their subsequent averaging.

With the help of the developed complex, the Biot-Savart-Laplace law and the principle of superposition of the magnetic field for circular currents of different diameters, with different currents flowing through the circuit were verified using a graphical method.

It is established that the error of measurements of current strength and magnetic field induction does not exceed 10%.

Keywords. Microcontroller, Conductor, Circular Currents, Measurements of Current Strength, Biot-Savart-Laplace Law, Magnetic Field.

1. Introduction

Comprehensive knowledge of any physical phenomenon is achieved by observations and experiments with the unification of thought, word (record) and action. At the same time, the majority of school graduates, formulating laws and remembering various definitions, can hardly explain the simplest physical phenomena, that is, they do not possess the techniques of experimental work.

To get a complete picture of the phenomena being studied, young experimenters need to: do their own experiments, conduct observations, measure, etc. A student can go through all the stages of quantitative cognition of a phenomenon by performing independent laboratory work, in which mental activity is also accompanied by the activity of the organs of movement (motor).

The main components of magnetostatics are the law of Biot - Savart Laplace and the principle of superposition of the magnetic field [1], which allow to determine the force vector characteristic of the magnetic field (induction) of a conductor with a current of arbitrary geometric shape.

Therefore, the developed measuring complex will allow the student to verify in practice the basic laws of the magnetic field, and will also contribute to the formation of stable judgments about the phenomena studied. This will allow to get away from the formalism in the study of physics and magnetostatics in particular.

2. Designed laboratory setup

To study the magnetic field created by closed circuits and individual sections of conductors with current, a setup was developed consisting of two main components: a tablet and a measuring unit (Figure 1). In the center of the tablet, made of PCB, is a digital magnetic field sensor LSM303C [2]. The investigated conductor with current (CC) is fixed on the tablet with the help of thermoplastic glue; previously the contours of the conductor are applied with a marker. The ends of the conductor are threaded into one of the holes located on the surface of the tablet and are connected by connectors to the measuring unit.

The measuring unit (see Figure 2) contains: an ATmega 328 microcontroller (MCU), an analog current sensor ACS712 [3] (CS), a digital-to-analog converter (DAC), a voltage-current converter (CVC), a joystick control (J) and a liquid crystal screen (LCD), which displays: a module and three projections of the magnetic field induction vector, the current flowing through the conductor and the current adjustment step. The digital magnetic field sensor (MS) and the DAC are connected to the ATmega 328 via the I2C bus. The power supply

© 2019 HSci. ISBN 978-989-8798-06-0

of the tunable current source is carried out using high-current lithium-ion batteries (PS), this allows the developed complex to be made mobile.

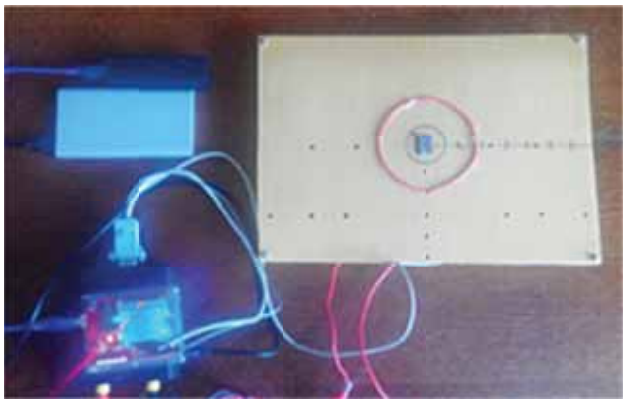


Figure.1 Designed setup

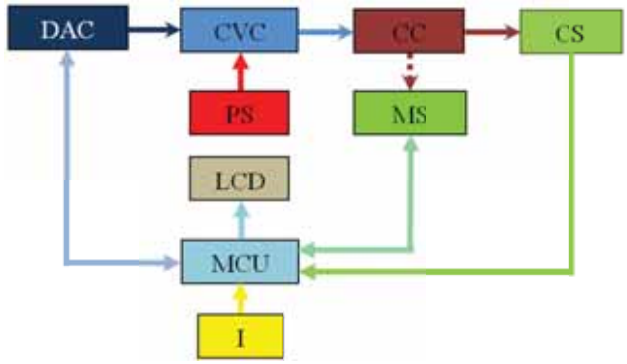


Figure. 2 The block diagram of the measuring unit setup

DAC and CVC are a controlled current source operating in the range from 0 to 3 A, with the smallest current tuning step of 12 mA. The DAC output voltage is converted to current flowing through a conductor (Figure 3). Moving the joystick up / down you can increase / decrease the value of the current flowing through the conductor, and when moving to the right / left - increase / decrease the step of adjustment of the current.

Since the output signal of the analog current sensor is voltage, the ACS712 sensor was calibrated (Figure 4). The voltage from the CS output goes to the analog MCU input, where it is digitized and averaged. By approximating the data obtained by the least squares method, a ratio was obtained which allows to recalculate the voltage into the measured current.

When the current does not flow through the conductor, the values of the "magnetic background" (Bx, By, Bz, B) in μT are displayed on the screen, due to the Earth's magnetic field and other sources of the magnetic field; the second line displays the data of the set value of the current through the conductor and the step of the current adjustment.

When you press the joystick button, the measurement mode is started and in the first line the current measured using CC value (I_e) and magnetic induction value (including "magnetic background") averaged over 200 values are displayed on the screen. The second line shows the values of the set values of the current and the step of adjustment (see Figure 5). In the upper right corner appears the inscription "On", indicating the operation of the setup in the measurement mode.

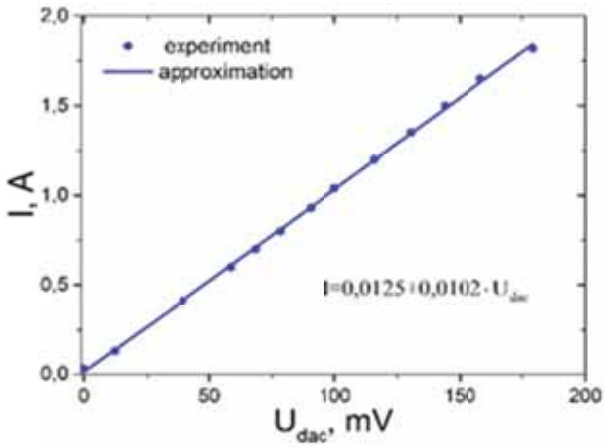


Figure.3 Dependence of the current at the output of the controlled current source on the output voltage DAC

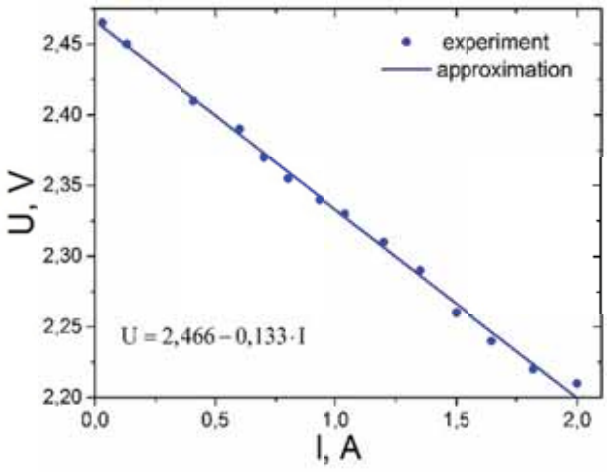


Figure. 4 The dependence of the output voltage of the ACS712 sensor on the flowing current

An experimental verification of the law of Biot-Sawart-Laplace and the principle of superposition of a magnetic field for a circular current (Figure 6) was performed in the work.

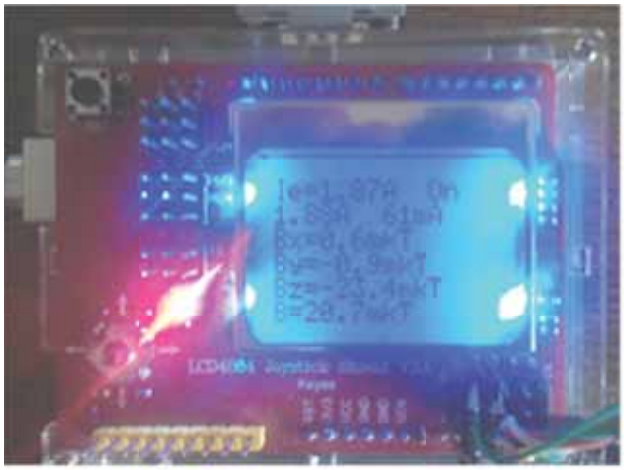


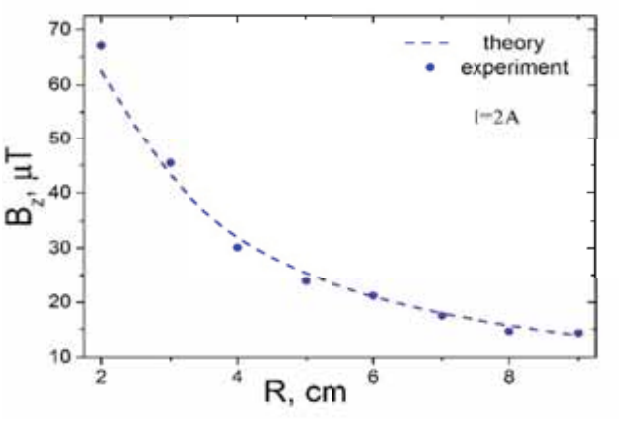
Figure. 5 Data obtained in the presence of current in the conductor

At the same time, the current strength (Figure 6a) and the radius of the circular coil (Figure 6b) changed. It can be seen from the figure that the experimental points fit well the theoretical dependences. The measurement error does not exceed 10%.

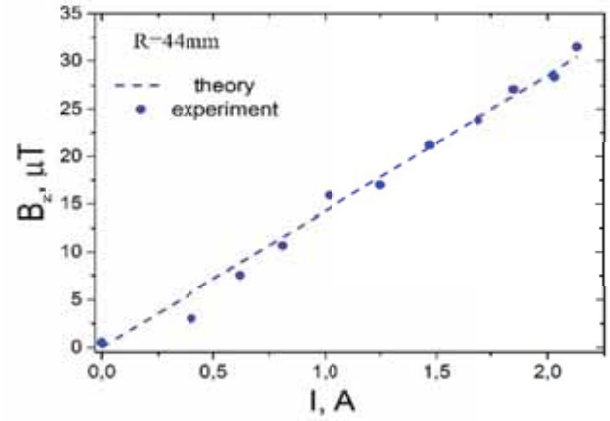
Since the current-carrying and test conductors are located in mutually perpendicular planes, only the projection of the magnetic field induction vector along the z axis is taken into account in the calculations. This allows you to significantly reduce the effect of auxiliary (supply) conductors with current on the measurement process.

The developed setup allows to check the principle of superposition of a magnetic field for closed circuits with a current of various geometric shapes: circular, square, triangular, etc., as well as to investigate the magnetic field created by individual sections of the conductor with current. Check the law of Biot-Savart-Laplace and the principle of superposition of the magnetic field.

It is also possible to connect several closed circuits, which makes it easy to verify the principle of the superposition of magnetic field induction. In this case, the student himself will have to calculate the values of the current strength through the conductors, taking into account their resistance (if there is one conductor, the current strength value will be displayed on the screen). If centimeter divisions are applied to the surface of the tablet, it is possible to investigate the magnetic field of the permanent magnets and determine their magnetic moment.



(a)



(b)

Figure. 6 Experimental verification data of the magnetic field of the superposition principle and the law of Biot-Savart-Laplace

3. References

[1] Serway RA, Jewett JW. Physics for Scientists & Engineers with Modern Physics. Boston: Physical Sciences: Mary Finch, 2014.

[2] https://www.st.com/resource/en/datasheet/dm00089896.pdf

[3] http://www.alldatasheet.com/datasheet-pdf/pdf/168326/ALLEGRO/ACS712.html