IJEES

International Journal of Electrical Engineering and Sustainability (IJEES)

ISSN (online): 2959-9229

https://ijees.org/index.php/ijees/index

ISI 2023-2024: (0.557) Arab Impact Factor: 1.51 SJIF 2024 = 5.274

Volume 3 | Number 2 | April-June 2025 | Pages 58-64

Article

# A Low-Cost Magnetic Field Strength Monitoring System Based on Arduino and Magnetic Sensor

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Received: February 04, 2025 Accepted: April 08, 2025 Published: April 09, 2025



**Abstract:** Developing a magnetic field tester plays a vital role in ensuring precise measurement and effective analysis of magnetic fields across a wide range of applications, including industrial processes, scientific research, and educational settings. This project presents the design of a compact and user-friendly device capable of detecting and accurately measuring magnetic field strength and direction. The system utilizes microcontroller (Arduino Uno) and Hall-effect sensor known for its sensitivity to magnetic variations, enabling real-time monitoring of magnetic field characteristics. The tester is engineered with a strong focus on accuracy, reliability, and operational simplicity. It features a microcontroller for processing sensor output and an LCD screen that displays the magnetic field strength in both digital and analog forms. Additionally, the device includes a calibration mechanism to maintain measurement consistency in varying environmental conditions, enhancing its dependability and precision in practical applications.

**Keywords:** KY-024 Linear Magnetic Hall Sensor, AVR Microcontroller (Arduino Uno).

## 1. Introduction

The proposed system utilizes a serial input configuration and is designed to operate on microcontroller platforms such as Arduino, ARM, or Raspberry Pi. Among these, the Arduino Uno is identified as the most suitable due to its simplicity, cost-effectiveness, and ease of deployment. The Arduino Uno board is powered by a 16 MHz crystal oscillator and integrates all necessary components to support its microcontroller. The board can be easily interfaced with a computer via a USB connection or powered externally using an AC-to-DC adapter or battery. Programming is performed using the Arduino Integrated Development Environment (IDE) in the Arduino programming language [1,2].

A key objective of the project is to measure and visualize magnetic field strength. Magnetic fields are often represented by magnetic field lines, with the density of these lines indicating the field's intensity. The total number of magnetic lines passing through a given surface area is referred to as magnetic flux, measured in weber (Wb), which is equivalent to tesla·meter² ($T \cdot m^2$). Legacy units such as the Maxwell (1 Maxwell = $10^{-8}$ Wb) and the gauss (1 gauss = $10^{-4}$ T) are now largely obsolete. The magnetic flux density decreases with increasing distance from a current-carrying conductor or between two magnetic poles with a stable magnetic field. At any given point near such a conductor, magnetic flux density is directly proportional to the electric current. Furthermore, when a ferromagnetic object, such as iron, is introduced into a magnetic field, the magnetic force acting on the object is proportional to the gradient of the magnetic field strength at that location [3,4].

This study proposes a method to measure magnetic field strength using a microcontroller-based system, specifically leveraging the Arduino platform. The Arduino Uno features six analog-to-digital converter (ADC) channels, any of which can be utilized for analog voltage input. The onboard ADC offers 10-bit resolution, allowing it to convert analog voltage in the range of 0 to 5 volts into digital values ranging from 0 to 1023. Consequently, each step corresponds to approximately 4.9 mV (5 V / 1024 steps) [6]. To demonstrate this functionality, a potentiometer is connected to analog input pin A0, and the resulting ADC values are displayed on a character LCD screen. The visual output is handled via a 16×2 alphanumeric LCD module, which consists of two rows with 16 characters each. Each character is rendered through a 5×10-pixel matrix, controlled by an integrated HD44780 controller embedded within the display. This controller handles the low-level pixel operations, thus simplifying the interface for the user [4-5]. According to a recent study [6], low-field magnetic resonance imaging (MRI) is emerging as a valuable diagnostic tool due to its relatively simple magnet array design, which allows for the development of accessible and portable scanners. This simplicity makes it especially suitable for integration into educational workshops, promoting hands-on learning and facilitating knowledge transfer to local scientists and engineers. Such initiatives empower communities to develop customized solutions that address region-specific healthcare challenges. As documented by Marsic [7], non-destructive testing (NDT) plays a critical role in sectors such as medicine, aerospace, defense, and heavy industry, particularly for assessing equipment prone to corrosion and concealed structural faults. Among the established NDT techniques for inspecting steel structures, magnetic flux leakage (MFL) detection stands out as a mature and widely utilized method.

This study contributes to the advancement of low-cost, portable instrumentation by developing a reliable and accurate magnetic field tester tailored for diverse applications in industrial diagnostics, scientific research, and educational demonstrations. The proposed system integrates a Hall-effect sensor with an Arduino Uno microcontroller to facilitate real-time detection and precise measurement of magnetic field strength and polarity. Its compact design and intuitive user interface, including an LCD display and a calibration mechanism, ensure ease of use, measurement consistency, and operational robustness under varying environmental conditions. Base on prioritizing accuracy, reliability, and simplicity, this device provides a practical and accessible solution for magnetic field characterization, thereby promoting wider adoption of sensor-based magnetic diagnostics in resource-limited or field-based settings.

## 2.Methodology

### *A. Magnetic Sensor-Based Arduino Circuit with I2C LCD and Buzzer*

This project involves the integration of several electronic components with an Arduino Uno to create an interactive circuit that outputs magnetic field data. The components used include an Arduino Uno, a KY-024 magnetic sensor, a buzzer, and an I2C LCD display [8-13]. The system functions as a simple interface for detecting changes in the magnetic field and displaying corresponding information on the LCD screen, while simultaneously triggering an audible alarm through the buzzer as shown in Figure 1.

- Arduino Uno: The Arduino Uno is the central microcontroller in this circuit. It is programmed to read inputs from the KY-024 magnetic sensor, process the data, and control both the LCD display and the buzzer based on the magnetic field detection. The Uno's GPIO pins are used to interface with these components.
- KY-024 Magnetic Sensor: The KY-024 is a magnetic field sensor that outputs analog data depending on the proximity of a magnetic object. The sensor operates based on the Hall effect, which occurs when a magnetic field interacts with a conductive material. The sensor provides a variable voltage output that is directly related to the strength of the magnetic field detected. This analog signal is read by one of the analog pins on the Arduino Uno for further processing.

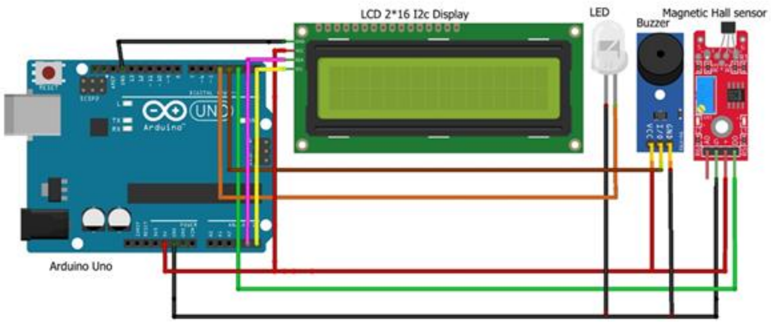


**Figure 1.** The practical circuit connection in Fritzing software.

- LCD Display (I2C): An I2C LCD display is used in this setup to provide real-time feedback to the user. The I2C interface simplifies the wiring by reducing the number of pins required for communication between the Arduino and the LCD screen. The display will show values related to the magnetic field strength or indicate the detection status of the sensor, offering a visual output to complement the audible feedback.
- Buzzer: The buzzer is connected to a digital pin on the Arduino. Based on the sensor's output, the Arduino can activate the buzzer to produce an audible sound when a magnetic field is detected. This feature serves as an immediate alert to the user, making the system useful for applications that require instant notification.

B. *Circuit Operation Hardware*

The circuit begins by continuously monitoring the analog output from the KY-024 magnetic sensor. When a change in the magnetic field is detected, the Arduino processes this change and adjusts the display output on the LCD accordingly [14,15]. If the magnetic field exceeds a predetermined threshold, the Arduino triggers the buzzer, notifying the user of the event. Simultaneously, the LCD will display relevant information about the magnetic field strength or simply indicate whether the sensor has detected a magnetic presence.

The interaction between the KY-024 sensor and the Arduino Uno allows for dynamic responses based on environmental changes, making this circuit suitable for applications like magnetic field detection, proximity sensors, or as part of a larger security system. This circuit demonstrates the integration of an analog sensor (KY-024) with a microcontroller (Arduino Uno) to monitor and display magnetic field data in real-time. The use of an I2C LCD and a buzzer enhances the feedback mechanisms, providing both visual and auditory alerts. This setup is an excellent starting point for projects requiring magnetic field detection and can be expanded for more complex applications as shown in Figure 2.

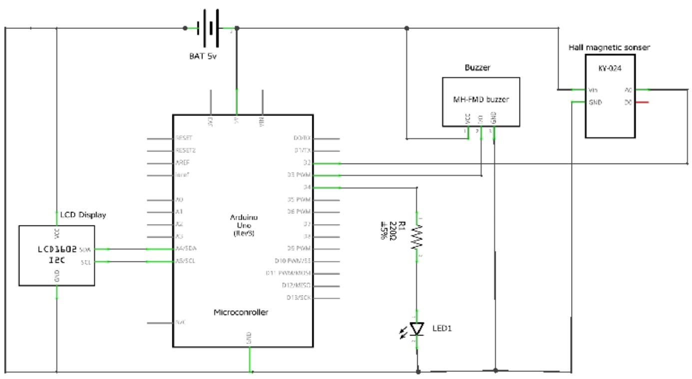


**Figure 2.** Bloc Diagram Circuit Operation.

The block diagram in Figure 2 illustrates a simple yet effective magnetic field detection system that integrates the KY-024 Hall Effect sensor with an Arduino Uno microcontroller. The KY-024 sensor provides both analog and digital outputs, enabling the Arduino to monitor magnetic field strength in real-time. When a magnetic field is detected, the Arduino processes the sensor data and triggers both visual and auditory alerts through an LED and a buzzer, respectively [16-18]. An I2C LCD display is also incorporated to provide clear textual feedback, such as displaying "Magnetic Field Detected," enhancing the user interface. The system is powered by a 5V battery, making it suitable for standalone operation. This circuit is ideal for applications such as intrusion detection, proximity sensing, and educational demonstrations. Its modular and scalable design allows for future expansion, including data logging, wireless communication, or integration with IoT platforms. Overall, this setup serves as a practical foundation for projects requiring real-time magnetic field monitoring and offers flexibility for further development into more complex systems.

## 4.Results and Discussion

### *A. Reading Behavior with North and South Magnetic Poles Using a Magnetic Field Intensity Sensor*

In fact, the positive and negative values observed from the sensor are determined by the direction of the magnetic field rather than its strength alone. A Hall effect sensor responds to magnetic fields by generating a voltage that varies depending on the field's orientation:

- A positive or elevated output is produced when the magnetic field is oriented in a particular direction (toward the upper surface of the sensor).
- A negative or reduced output is generated when the magnetic field is in the opposite direction.

However, since the KY-024 sensor does not produce truly negative voltages (values below 0 volts), what is commonly referred to as a "negative value" likely denotes:

- A decrease in the analog output voltage when a specific magnetic pole (the south pole) is brought near the sensor.
- An increase in output voltage when the opposite pole (the north pole) is brought closer.

Practical Illustration:

- When the north pole of a magnet is brought near the sensor, the analog output may rise significantly (4 volts).
- Conversely, approaching the south pole may reduce the output voltage to around 1 volt.

This behavior is a result of the Hall sensor's internal orientation, which is sensitive primarily to the direction of the magnetic field rather than its magnitude as presented in the Table 1.

Table 1: Practical Illustration.

| Effect on Signal | Field Direction | Magnetic Pole |
|---|---|---|
| Increase in voltage | In a specific direction | North (N) |
| Decrease in voltage | Opposite direction | South (S) |

### *B. Technical Interpretation of Magnetic Field Polarity in Sensor Readings*

At a fixed distance of 1 cm between the magnetic sensor and each magnetic pole, the observed magnetic field values exhibited opposite polarities: a negative reading of -364.13 was recorded when the north pole faced the sensor, while a positive reading of 354.35 was obtained with the south pole at the same distance and orientation as illustrated in Figure 3.

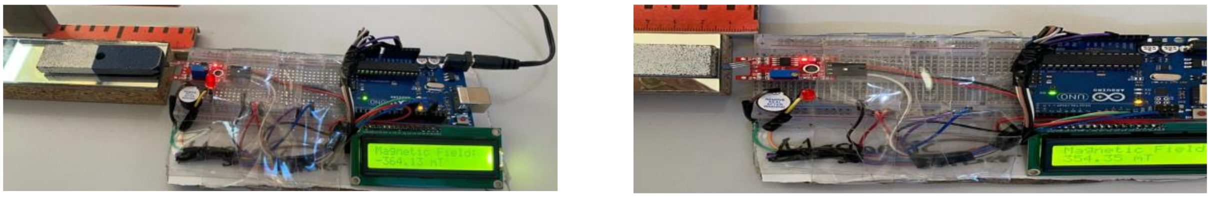

**Figure 3.** Magnetic Field Polarity in Sensor Readings.

This variation in sign does not reflect the presence of "positive" or "negative" magnetic fields in a physical sense, but rather corresponds to the direction of magnetic flux relative to the sensor's reference axis. In magnetic field sensors, particularly Hall-effect or magneto resistive types, the sign of the output is determined by the direction in which the magnetic field lines intersect the sensitive axis of the sensor.

- A positive value indicates that the magnetic flux is entering the sensor along the reference axis in the defined positive direction (outward from the sensor surface).
- A negative value signifies that the flux is oriented in the reverse direction (into the sensor surface).

This behavior is consistent with the fundamental characteristics of magnetic fields, which emerge from the north pole of a magnet and enter the south pole. Therefore, when the sensor is held in a fixed orientation, the approach of opposite poles naturally results in magnetic fluxes with opposing directions relative to the sensor. This directional difference is what causes the polarity inversion in the recorded measurements. In summary, the sign of the measured magnetic field is an indicator of field direction rather than magnitude or intensity, and it directly reflects the spatial orientation of the magnet relative to the sensor's sensitive axis. As presented in the Table 2 and Table 3.

Table 2: South Pole (White Color).

| Reading Value (mT) | Sensor Distance | Buzzer | Led |
|---|---|---|---|
| 354.35 | 1cm | ON | ON |
| 26.88 | 2cm | ON | ON |
| 21.99 | 3cm | ON | ON |
| 36.66 | 4cm | ON | ON |
| 46.43 | 5cm | ON | ON |
| 0 | 6cm | Off | Off |

Table 2 presents the response of the magnetic field detection system when exposed to the south pole (white color) of a magnet at varying distances from the sensor. The data clearly demonstrate a correlation between sensor proximity and magnetic field strength, with the highest reading of 354.35 mT recorded at a distance of 1 cm. As the distance increases, the detected magnetic field strength decreases, showing values such as 26.88 mT at 2 cm, 21.99 mT at 3 cm, and eventually dropping to 0 mT at 6 cm, where the magnetic field is no longer detectable by the sensor. Throughout the 1 cm to 5 cm range, the system successfully identifies the magnetic field and activates both the buzzer and LED, providing consistent visual and auditory alerts. However, at 6 cm, the absence of a detectable field results in both the buzzer and LED being turned off. This pattern confirms that the KY-024 sensor is sensitive to magnetic fields within a 5 cm effective range and highlights the system's reliability in distinguishing magnetic presence based on threshold detection. The results validate the setup's functionality for real-time proximity and field strength monitoring and suggest its applicability in applications requiring accurate magnetic field detection within short distances.

Table 3: North Pole (White Color).

| Reading Value (mT) | Sensor Distance | Buzzer | Led |
|---|---|---|---|
| -364.13 | 1cm | ON | ON |
| -124.63 | 2cm | ON | ON |
| -21.99 | 3cm | ON | ON |
| -80.65 | 4cm | ON | ON |
| -65.98 | 5cm | ON | ON |
| 0 | 6cm | Off | Off |

Table 3 illustrates the system's response to the north pole (white color) of a magnet at varying distances from the KY-024 magnetic field sensor. Similar to the results for the south pole, the system consistently detects the magnetic field and activates both the buzzer and LED at distances ranging from 1 cm to 5 cm. The sensor registers the highest magnetic intensity of -364.13 mT at 1 cm, with the field strength decreasing as the distance increases, reaching -124.63 mT at 2 cm and progressively diminishing to -65.98 mT at 5 cm. At 6 cm, the sensor records 0 mT, indicating the absence of a detectable magnetic field, resulting in the buzzer and LED turning off. Notably, the negative values reflect the polarity of the magnetic field, distinguishing the north pole from the south. The system reliably differentiates magnetic presence through polarity and magnitude, confirming its effectiveness for bidirectional pole detection. This consistent behavior across both polarities demonstrates the versatility and accuracy of the detection system, making it suitable for a wide range of magnetic sensing applications that require both proximity and polarity identification.

## 5.Conclusion

This article provides a summary of the principal outcomes and achievements of the project, highlighting the design, analysis, and implementation phases of the magnetic field tester. The project successfully resulted in the development of a portable and user-friendly device capable of accurately measuring and displaying magnetic field strength. By integrating a Hall-effect sensor with a microcontroller-based system, the project ensured precise and reliable measurements. The comprehensive design process played a crucial role in meeting the required performance and durability standards for the device. The technical drawings, calculations, and specifications presented in the practical aspect reflected a methodical and well-organized approach to system design, which ultimately contributed to the successful realization of the prototype. Furthermore, the cost estimation provided valuable insights into the financial aspects of the project, ensuring that the design remained both cost-effective and feasible. During the implementation phase, the device's functionality was thoroughly validated, confirming its effectiveness in real-world conditions and demonstrating its ability to fulfill the requirements of its intended users.

**Author Contributions:** Author has contributed significantly to the development and completion of this article.
**Funding:** This article received no external funding.
**Data Availability Statement:** Not applicable.
**Acknowledgments:** The author would likes to express their sincere gratitude to Bright Star University, Libya for their invaluable support and resources throughout the course of this research.
**Conflicts of Interest:** The author(s) declare no conflict of interest.

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