



To Design and Build a Portable Gaussmeter using Hall Sensor A3144

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ABSTRACT

A portable, low-cost Gaussmeter was designed and constructed using a Hall effect IC sensor A3144. The output Hall voltage was studied as a function of the input current of an electromagnet. The results were compared qualitatively to that of a commercial gaussmeter. Our constructed Gaussmeter was found to be a reliable device to successfully measure the magnetic field. Further, the sensitivity of the Hall effect Sensor, A3144 was quantitatively estimated for two different pull up resistances. It was found to be ~ 2 and 0.8 mV/mT for resistances 1 and 10 k Ω , respectively. An affordable, lightweight and portable gaussmeter using semiconductor technology was developed which can be used for magnetic field detection and pollution monitoring to safeguard both human health and the environment from the impacts of excessive magnetic fields.

Keywords: Gaussmeter, Hall sensor, magnetism, magnetic field

INTRODUCTION

Carl Friedreich Gauss, who was a great mathematician pioneering in the study of magnetic fields, was the inventor of one of the first magnetic field measuring devices, namely the magnetometer or Gaussmeter, in 1833. These devices are capable of measuring the direction and strength of a magnetic field [1]. A gaussmeter measures the magnetic flux density, B , at a specific location in space [2]. Hall-effect sensor components [3], working on the principle of Hall effect, are frequently used as magnetic field probes in gaussmeters today [4]. The Hall effect is a phenomenon caused by the deviation of the current flow in the presence of a magnetic field perpendicular to the flow of current, due to the Lorentz force. In the presence of the magnetic field the moving charges accumulate on one face of the material. This leaves equal and opposite charges exposed on the other face, where there is a scarcity of mobile charges. The result is an asymmetric distribution of charge density across the Hall element that is perpendicular to both the current flow and the applied magnetic field, as shown in Fig. 1. The separation of charge

establishes an electric field that opposes the migration of further charge, so a steady electrical potential is established for as long as the charge is flowing. It was discovered that the Hall voltage thus developed was proportional to the strength of the magnetic field, which makes the Hall effect an ideal magnetic field sensing technology. Contemporary Hall elements are predominantly fabricated within semiconductor materials such as silicon (Si), indium arsenide (InAs), gallium arsenide (GaAs), and indium antimonide (InSb).

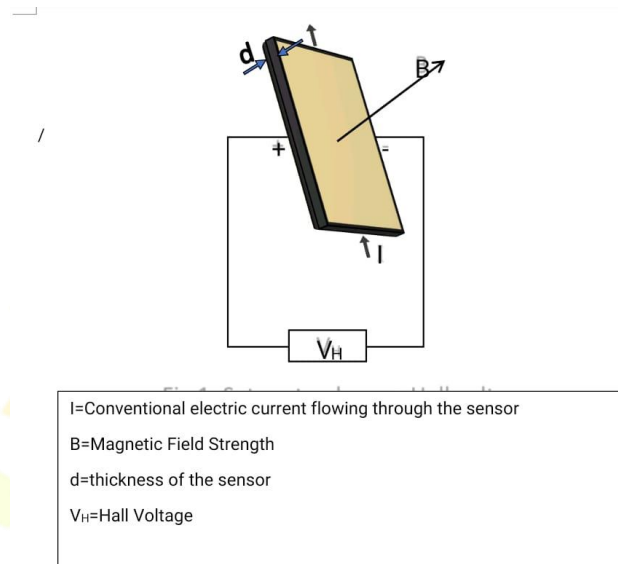


Fig 1: Set-up to observe Hall voltage

The advent and mass production of affordable integrated circuits marked a significant advancement, enabling the integration of Hall effect sensing components with electronic circuitry on a single chip. This breakthrough opened the door to a multitude of applications. Hall effect devices, which initially began as a means to measure magnetic fields, have since evolved into indispensable components for sensing pressure, current, location, and temperature through magnetic field-based techniques.

Portable Gauss meters are popular, simple and inexpensive magnetometers. They are advantageous over other magnetometers as they are portable, light weight, convenient to operate and sensitive. Hall effect devices are properly packed to make them immune to dust, dirt, mud, and water. These characteristics make Hall effect devices better for position sensing than the optical and electromechanical sensors. In the modern digital era, these meters play a crucial role in identifying and addressing the phenomenon known as "magnetic pollution." This term refers to the emergence of undesirable or disruptive magnetic fields within a given space, which have the potential to hinder the proper functioning of electrical appliances, intricate machinery, and even biological systems. A wide array of both natural and artificial sources can give rise to these magnetic fields. Examples encompass power lines, transformers, electronic gadgets, industrial procedures, electronic interference stemming from various devices, as well as the magnetic resonance imaging (MRI) machines utilized in medical contexts.

These devices can also be used for determining whether any inert or active electromagnetic fields are influencing the exact electronic devices working at the location of their installation. While certain magnetic fields are an intrinsic aspect of contemporary living due to diverse technological implementations, apprehensions regarding magnetic pollution surface when these fields attain intensities capable of causing undesirable disruption, health issues, or adverse impacts on the operational efficiency of equipment.

EXPERIMENTAL DETAIL

The constructed gauss meter consists of a probe on which the Hall sensor can be attached and associated electronics constructed on a Printed circuit board (PCB), as shown in Fig. 2. The probe gets the input from a 9V battery. A low-drop fixed voltage regulator IC 7805, which provides a constant DC power source (+5V) to the Hall effect sensor, is utilized to ensure that the meter readings are stable during the course of the battery. In addition, the circuit utilizes, two pull up resistance of 1 and 10 k Ω , Capacitors of 2.2 and 100 μ F. A Light emitting diode (LED) is an indicator which was used in the circuit to ensure that the circuit was working and there was supply from the battery. An electrical switch was used to control the flow of electrical current within the circuit. For the Hall sensor itself, A3144 Hall effect IC [6] was used. A3144 is a popular Hall Effect sensor integrated circuit (IC) utilized in a variety of sensing and detection applications [7]. It is optimized to accurately provide a voltage output that is proportional to an applied magnetic field.

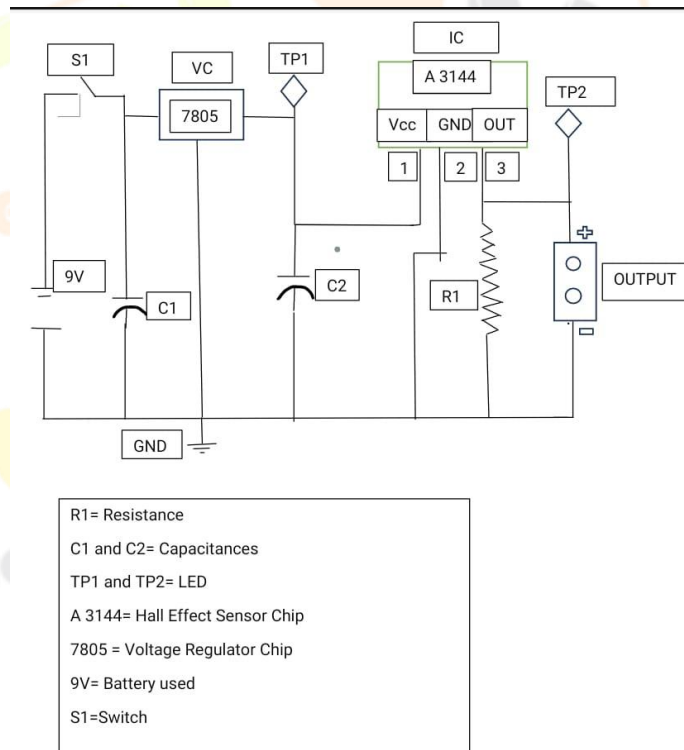


Fig. 3: Circuit Diagram for the construction of Gaussmeter

For building the Gaussmeter, first the PCB, wires and the terminal contacts of each element were cleaned using sandpaper to ensure the surfaces were rust free for a perfect contact between the components. The components were placed on the PCB according to the circuit diagram to build the voltage regulator and pull-up part of the Gaussmeter. The relevant connections were made by gently bending the terminals and soldering carefully to obtain the required circuit. The voltage regulator circuit was connected to a switch and a battery (9V) as per the circuit diagram. The output of the voltage regulator circuit was connected to the input of the Hall sensor IC A3144 through the probe constructed using an empty pen cap. Ground was common.

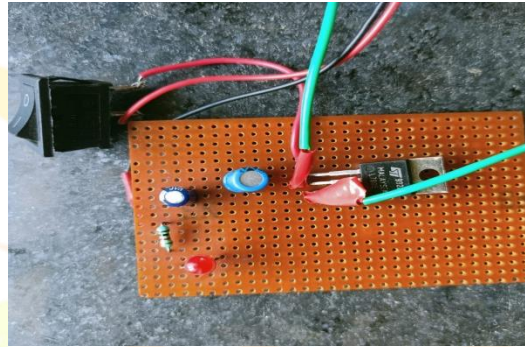


Fig. 4: The circuit constructed on the PCB

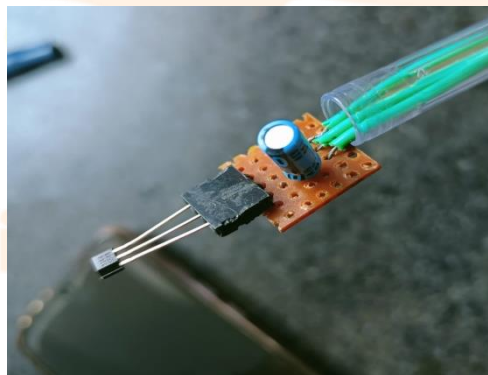


Fig. 5: The Hall probe using Hall sensor IC A3144

The gaussmeter was then calibrated by placing The Hall sensor IC in a stable position between the two poles of an electromagnet, the magnetic field of which was regulated using a power supply. As the input current of the electromagnet was varied to get different magnetic field strengths, the output Hall voltage of the constructed Gaussmeter was measured using a multimeter with one end at the output of the Hall sensor IC A3144 and the other to the ground terminal. The behavior of the Hall voltage as a function of input current and consequently the

magnetic field was compared to that obtained using a commercial digital Gaussmeter.

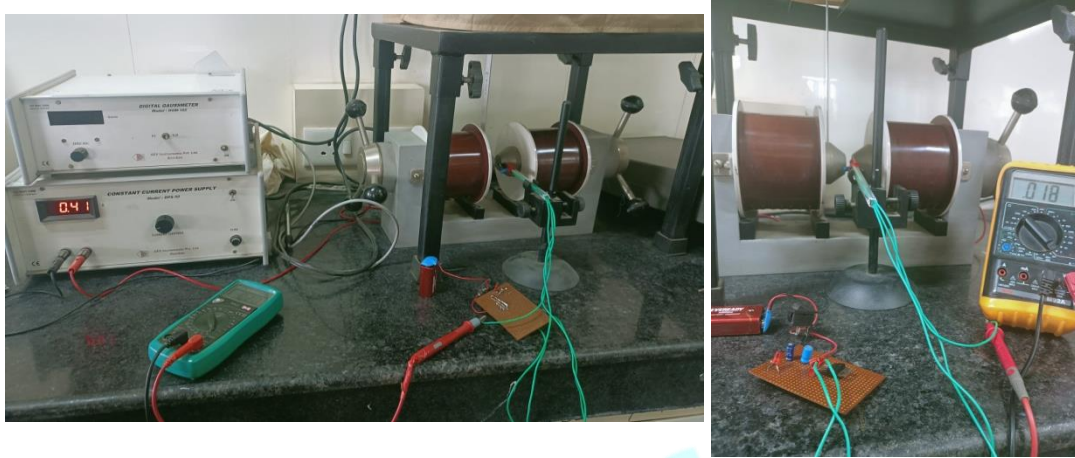


Fig. 6: Setup for measurement using the constructed Gaussmeter

RESULTS AND DISCUSSION

Fig. 7 shows the Hall voltage detected as the output of our Gaussmeter as a function of the current that was provided to the electromagnet. It is visible that the Hall voltage varies linearly with the current and consequently the magnetic field strength of the electromagnet. Further the inset of Fig.7 shows the variation of the magnetic field of the electromagnet with the input current as calibrated using a commercially available digital gaussmeter. It is again observed to exhibit a linear behaviour. Comparing the calibration curve for the electromagnet to that obtained from our Gaussmeter, it is clear that our constructed gaussmeter is a reliable tool for magnetic field detection within limits of experimental error.

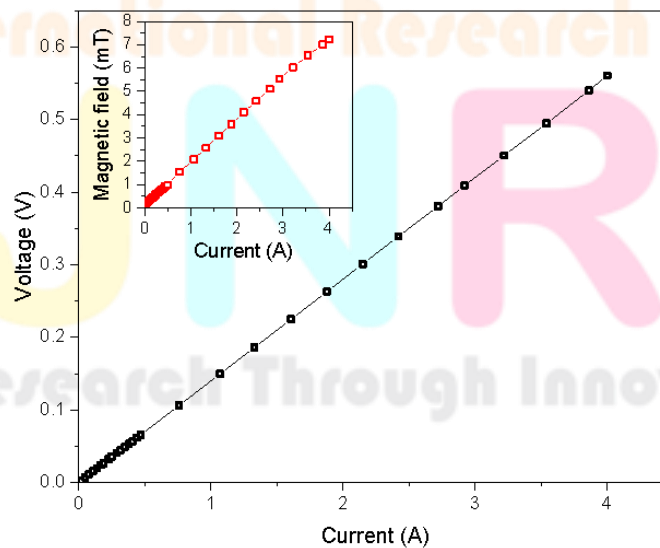


Fig. 7: Voltage vs. Current for constructed Gaussmeter (1kΩ); inset: Magnetic field vs. Current for commercial gaussmeter.

Further, the same measurements were performed by changing the pull resistance from 1 to 10 k Ω . The observed variation of Hall voltage with the current is shown in Fig. 8. It is seen that there is no change in the behavior of the Hall voltage as a function of the input current for the electromagnet but the two curves diverge as current increases.

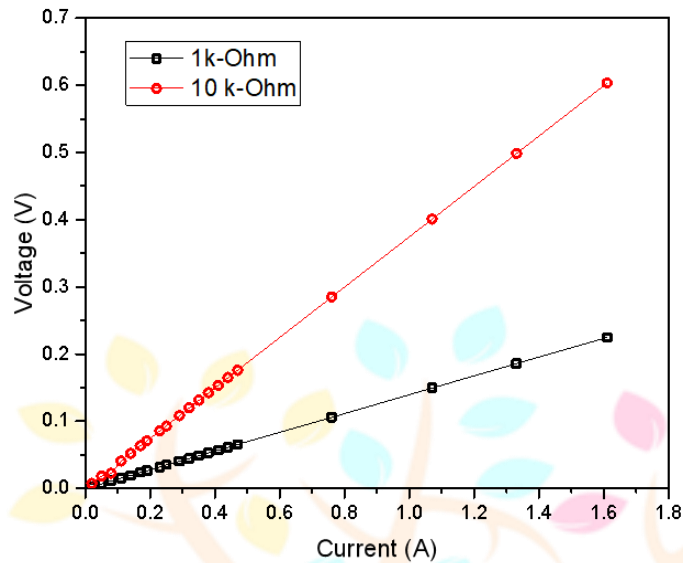


Fig. 8: Voltage vs. Current at two pick up resistances (1 and 10 k Ω)

We also attempted to determine the sensitivity of the Hall sensor A3144, measured in units of mV/mT, from the slope of the Hall voltage and corresponding magnetic field plot, as shown in Fig. 9. It was found to be ~ 2 mV/mT and 0.75 mV/mT for resistances 1 k Ω and 10 k Ω , respectively.

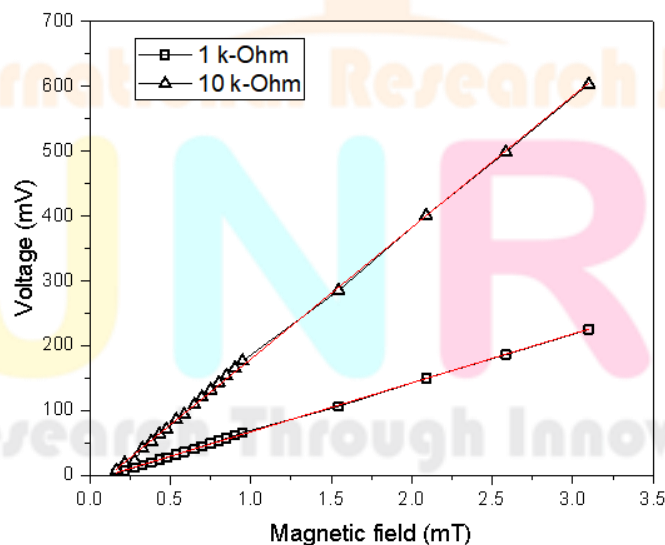


Fig. 9: Voltage vs Magnetic field for the two pick up resistances; red lines are linear fits to the data.

CONCLUSION

The portable Gaussmeter using Hall sensor A3144 was designed and constructed successfully. The sensitivity of the A3144 was determined for the two pull-up resistances. In its basic configuration, our developed gaussmeter demonstrates effective magnetic field detection capabilities. There is substantial promise for its integration with emerging technologies, thereby enhancing its efficiency and rendering it suitable for deployment as a dedicated tool for quantifying 'magnetic pollution'. This innovative device, utilizing advanced semiconductor materials, ensures precision and ease of use. It serves as a practical tool for identifying and addressing magnetic pollution concerns, benefiting environmental monitoring and public health.

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