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# A development of high sensitivity magnetic sensor based on giant magnetoresistance with simple implementation on smartphone

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**Abstract**

In this paper, the magnetic field-based sensor that can connect with smartphones through Bluetooth connectivity was developed. The design of this high sensitivity magnetic sensor system used Giant Magnetoresistance (GMR) sensors in the form of SOIC8 with AA002-02 series from NVE Corp. The results obtained from the measurements show that the sensor is able to work well when connected to an Android-based smartphone. Measurements were carried out by placing a magnet with a magnetic field strength of 0.4 T in the direction of the sensitivity plane of the GMR sensor. The result showed that the closer the magnet distance relative to the GMR sensor the more voltage signal output from the sensor. Since this developed method is simple but effective for detecting position of magnetic object, the further development of this method will be benefit for many applications.

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## INTRODUCTION

Magnetic sensor is one of the sensors with wide use in various fields of technology, such as automobiles, military, robotics, medical devices, space equipment, geophysics, industrial measurements etc. (Ripka & Arafat, 2019). The application of magnetic sensor including GMR sensor in military and secutiry such as detection, discrimination and localization of ferromagnetic and conducting objects, navigation, position tracking and antitheft systems (Ripka, 2013). Technology on magnetoresistance has provided greater magnetic field sensitivity, with smaller size, tolerance to high environmental conditions, low power performance, lower prices and many applications in various implementations (Guedes et al., 2018). GMR is widely used in many applications, including compass, automotive technology, and various kinds of motion sensors due to significant developments (Kapser et al., 2013). The basic principle of GMR is the change of resistance in the multilayer (bilayers/tri layers) in which magnetic layer separated by nonmagnetic layer under applied magnetic field (Patankar et al., 2022). The GMR sensor is designed to measure and detect magnetic field strength in various fields of technology applications. GMR sensor is very sensitive to

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detect small changes in the magnetic field. So, it is possible to measure accurately displacement in a linear position detectors and transducers (Djamal & Ramli, 2017).

The discovery of the GMR effect opens the gates of subsequent innovations in both science and technology. In the beginning of GMR discovery, the impact is on the development of data storage technology and magnetic sensors (Ardiyanti et al., 2023). Currently, many scientists around the world are conducting research on magnetoelectronic and its applications in various fields of science and technology and its impact on completely new commercial products (Jogschies et al., 2015). Smartphones have become a basic tool in human life, because it has been supporting various activities of people's daily life. Many systems related GMR sensor has been developed using smartphones as an interface. In healthcare application, GMR sensor which connected with smartphone developed for clinical and non-clinical testing (Choi et al., 2016). Regrading position measurement, GMR sensor with the system connected to the smartphone used to guide a vehicle for wireless charging (Huang et al., 2018).

This research proposed the simple designs of GMR sensor device with the mobile phone as the sensor output data viewer. The two components of the system that were developed are the hardware for the GMR sensor system and the software for Android phones. The benefits of this research can be the basis for developing high-precision magnetic sensor systems in various application. With connectivity between GMR sensors and smartphones, it is expected that many GMR sensor applications will be implemented as a basis for developing the internet of things. By using cloud-based software, MIT App Inventor, allows to develop applications for Android phones based on web browsers.

## METHOD

The GMR series AA002-02 and AA004-02 GMR sensor products from NVE manufacturing are used in this study. Neodymium permanent magnet with magnetic field of 0.4 T are used as the material to be detected by the sensor. Configuration of the process for calibrating the GMR sensor show in the Figure 1.

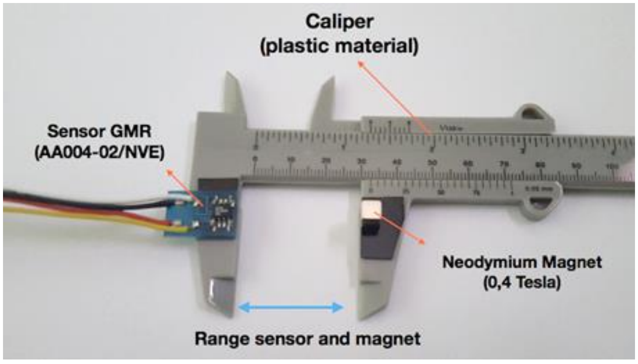


**Figure 1.** Calibrating the GMR sensor

We used caliper from plastic material instead of the metal one so the magnet cannot magnetize the caliper. Because this can affect the measurement result in calibration process. GMR sensor placed in the fixed jaw of caliper while the magnet placed in movable jaw. The distance between GMR sensor and magnet will vary with addition of 5 cm and the output voltage of the senor recorded. In Figure 2, the calibration result of the GMR sensor show the linearity and saturation of each x, y and z axis of sensor.

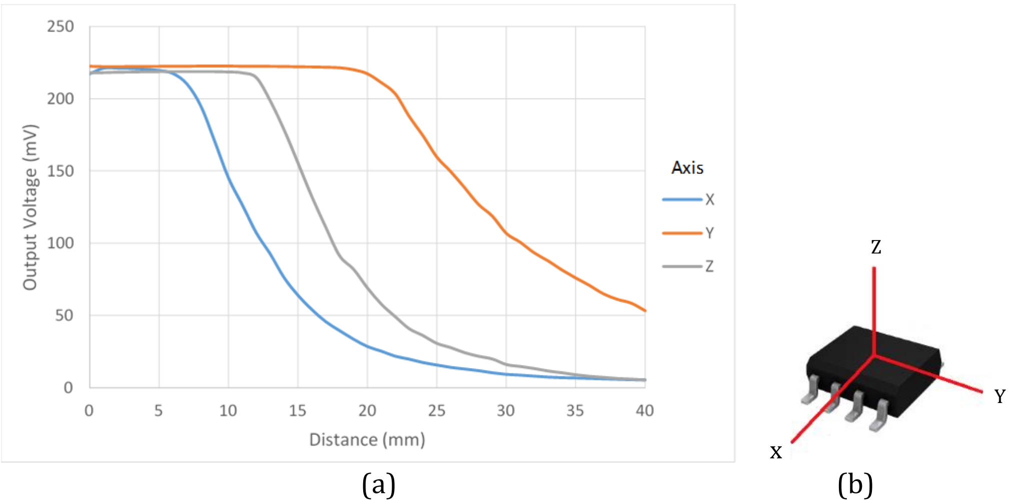


**Figure 2.** (a) Calibration data of GMR sensor and (b) Axis of measurement direction of sensor

Figure 2(a) show the data of the three axes have the same characteristics, but different in terms of sensitivity. The sensor is more sensitive in detecting changes in the magnetic field in the direction of the y-axis, which is according to the AA002-02 datasheet (NVE Corporation, 2019). On the y-axis, the sensor has detected the magnetic field and in its linear area or sensor working area at a distance of 4 cm. Meanwhile, on the x and z axes, the sensor has not detected the magnetic field at that distance. But in the y-axis, the magnetic field detection by the sensor has begun to saturate at a distance of 2 cm. Then at a distance above 2 cm, the sensor output voltage value on the y-axis is maximum and does not change any more. This data is used to determine the position of the sensor in the measurement or when we placed in the system.

Based on the result of calibration then y-axis of the sensor selected for further process of magnetic field mapping. Figure 3(b) shows a 3-dimensional graph of magnetic field mapping in y-axis direction at the surface of a neodymium magnet.

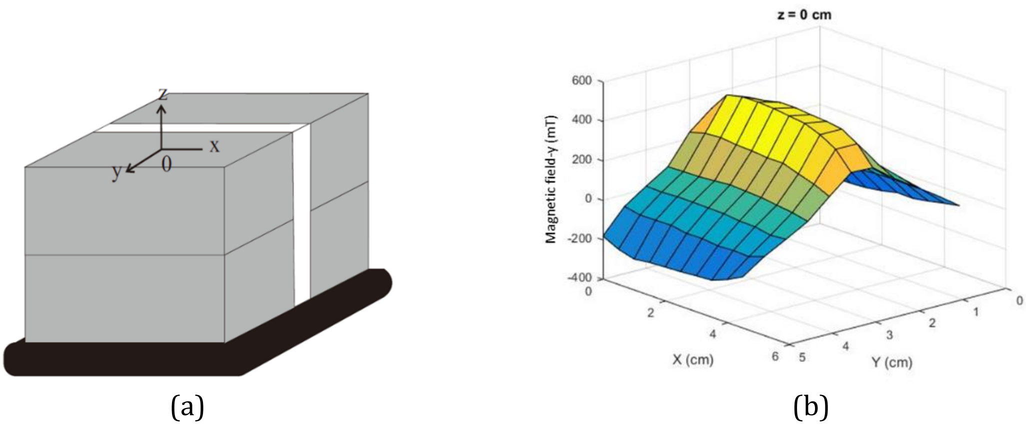


**Figure 3.** (a) Magnetic field direction at the top surface of magnet and (b) Magnetic field mapping in y-axis of the magnet

The GMR sensor generates a voltage proportional to the changing of magnetic field in static case. In case of dynamic magnetic field, this voltage proportional to the changing of magnetic field per area or magnetic flux which generated by the motion or rotation of the nearbymagnet through the sensor (Kilgore, 2017). For several applications, such as positioning and navigation, electronic stability programs, electrical current sensors, and biomagnetic field detection, magnetic field sensing is an essential task (Kittmann et al., 2018).

Under certain conditions, the voltage output signal from the GMR sensor could be very small. This is because the magnetic field detected by the sensor is very weak. In real application, the use of a GMR sensor is not always to measure the magnetic field of a magnet but an object with magnetic properties that is magnetized or produces magnetic field disturbances. For example, detecting passing vehicles by measuring the magnetic field disturbance produced by the metal on the vehicle (Pelegrí Sebastiá et al., 2007). For this reason, a signal conditioning circuit is used to pre-amplify the GMR bridge sensor output so that the data obtained can be analyzed properly. The signal amplifier used is a voltage amplifier which is referred to an instrumentation amplifier. The instrumentation amplifier IC that used in this circuit is INA118 as show in Figure 4. INA118 is an instrumentation amplifier that has high accuracy, low offset, low noise, low power, and can produce a gain of 1 – 10,000 by adjusting the $R_G$ resistor value given by following equation (Texas Instruments, 2022):

$$G = 1 + \frac{50\ k\Omega}{R_G} \qquad (1)$$

In this research, a gain of 1000 times was used by setting the $R_G$ value to 50 Ω.

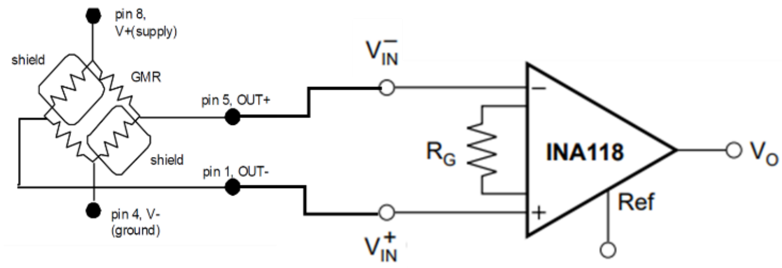


**Figure 4.** Signal Conditioning Circuit using INA118

## RESULTS AND DISCUSSION

The sensor system connected to an Android smartphone is simulated using Bluetooth. Basically we can use other types of connectivity such as WiFi, infrared, USB cable, etc. depending on the device used. The system prototype that was developed was then integrated using an Arduino Uno microcontroller as shown in Figure 5.

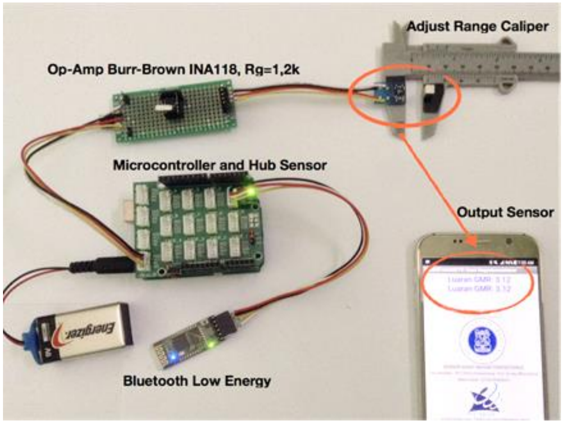


**Figure 5.** Prototype of GMR sensor system connected with android smartphone

The Arduino microcontroller program code was used by the IDE software to compile and code the microcontroller as in Figure 5. This system was tested again with the same configuration as when calibrating the sensor. The GMR sensor and magnet are attached to the caliper's jaw and then the distance changes in increments of every 1 mm. This measurement data is monitored via smartphone via an Android application developed using MIT App Inventor. It can be seen that increasing and decreasing the distance in the slider linearly affects the GMR sensor output and can be displayed in real time.

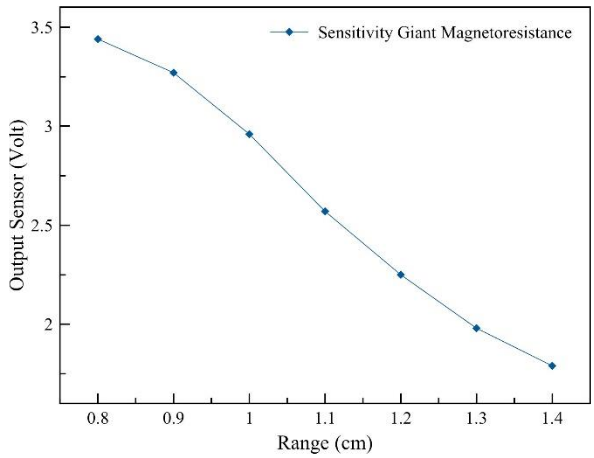


**Figure 6.** Graph output sensor vs range magnet

Based on the graph in Figure 6, the graph of sensor output against the distance of magnet relative to the sensor (range) shows a linear relationship. The sensor data displayed on the smartphone shows that the GMR magnetic sensor is very sensitive for every 1 mm increase in distance. This means that the sensitivity of the GMR sensor can be utilized in various measurement applications that use high accuracy such as detection object in translation or rotation motion, composition of metal content in liquids, robotics, power grid etc.

## CONCLUSION

A high sensitivity GMR sensor with simple implementation connected to a smartphone have successfully developed. The sensor system connected to the smartphone via bluetooth where the output of sensor can be displayed through applications designed using MIT App Inventor. The result showed that the closer the magnet distance relative to the sensor the more voltage signal output from the sensor. Since this developed method is simple but effective for detecting object with magnetic properties related to detection object in translation or rotation motion, composition metal content in liquids, current measurement etc. The further development of this method should enhance by filter circuit to handle AC signal form.

## AUTHOR CONTRIBUTIONS

A.B conceived and planned the experiments. A.B carried out the experiments. A.B. took the lead in writing the manuscript. C.D contributed to the final version of the manuscript.

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