Conference Paper

Development of Digital Scale Based on Fluxgate Sensor

Zannuraini, Mitra Djamal, and Widyaningrum Indrasari

[1]Institut Teknologi Bandung, Jl. Ganesa No. 10, Bandung 40132, Indonesia
[2]Institut Teknologi Sumatera, Jl. Terusan Ryacudu, Desa Way Hui, Kec. Jati Agung, Lampung Selatan 35365, Indonesia
[3]Universitas Negeri Jakarta, Jl. Pemuda No. 10, Jakarta Timur 13220

Abstract

Fluxgate is a magnetic sensor which works by comparing the measurement magnetic field with the magnetic field reference. This research aims to develop digital scales using fluxgate sensor. The steps involved were sensor development, characterization, distance and mass calibration of the fabricated sensor. Here, a digital scale based on fluxgate sensor with oval vitrovac 6025Z type core, 360 windings of excitation coil and 240 windings of pick up coil was successfully fabricated. Characterization result shows that the sensor has 1669.2 mV/μT sensitivity and working area of about $\pm$ 1.9 μT, with maximum absolute error found out to be around 0.0573 μT with maximum relative error is 1.464%. Calibrated sensor value obtained reveals that the sensor works from 15.86 until 27.00 mm in distance, utilizing equation of relationship between mass and output voltage $m(V_o) = 418,79V_o^2 - 346V_o - 134.32$ with the maximum relative error obtained as low as 1.49%.

Keywords: Digital scale, Fluxgate sensor, mass calibration, ferromagnetic core

Corresponding Author: Zannuraini; email: zannuraini91@gmail.com

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1. Introduction

Fluxgate is a magnetic sensor which works by comparing the measurement magnetic field with the magnetic field reference. The advantages of this sensor are small dimension, high temperature stability, low power consumption [1] compared to other available magnetic sensor, makes the measurement of very low magnet field 10^{-1} – 10^{6}nT become possible, with high linearity and great sensitivity, reliability, relative simple, and more economical [2]. In order to improve the quality and output sensor, various studies has been reported by other researchers by modifying the ferromagnetic core structure [3], dimension and structure sensor, along with signal processing circuit. Various method has been reported in the development of sensor making such as conventional method (winding wire conventionally), Printed Circuit Board (PCB), micro technology, and hybrid [4]. Other variables that give effect to sensor output are geometry sensor, coil configuration, layer quantity and material of ferromagnetic core [1]. Other possible applications utilizing fluxgate sensor are vibration sensor [5], detector of magnetic material in soil subsurface [6], non-contact current and displacement measurements [7], etc. In this work, we aim to develop a digital scale utilizing fluxgate sensor.

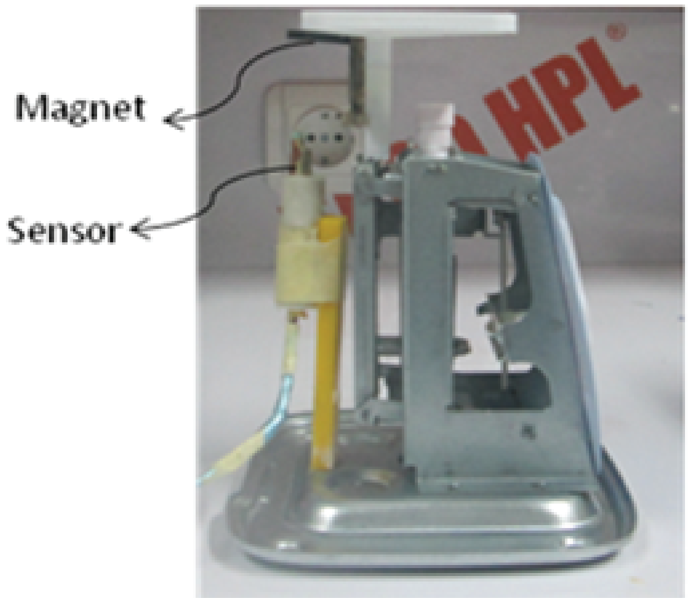

Figure 1: Frame of spring scale.

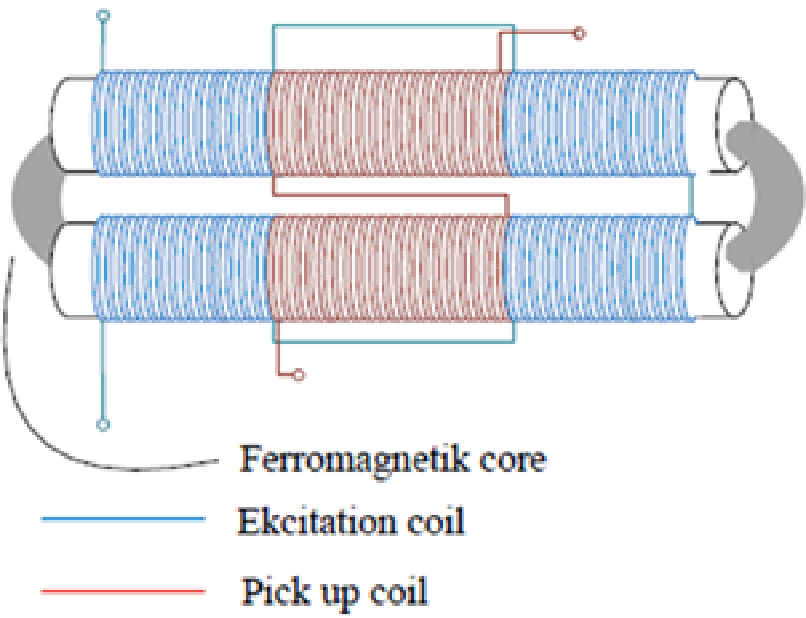

Figure 2: Design of fluxgate sensor element.

2. Method

The development of digital scale based on fluxgate sensor study used a frame of spring scale that has modified with addition fluxgate sensor, and magnet which generates a magnetic field 33.7 mT on its surface, as shown in Figure 3.

When load was put on the scale, the distance between sensor and magnet will decrease and the voltage output of sensor will increase, this change of voltage output is converted to mass quantity.

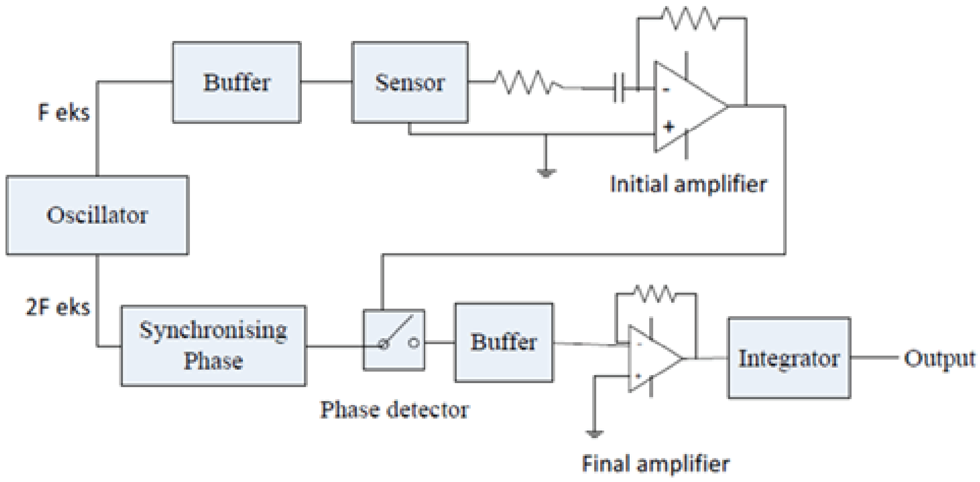

Figure 3: Scheme analog signal processing circuit.

Conventional fluxgate sensor fabricated in this study comprises of two pick up coils and four excitation coils. Each excitation coil consists of 90 windings while the pick-up coil consists of 120 windings. This coil is rolled on the sleeve insulator, and ferromagnetic core is inserted into the sleeve, as shown in the fig 3. The shape of ferromagnetic core is oval, chosen due to the core relatively symmetry results in low demagnetization effect and high sensitivity. The ferromagnetic core is Vitrovac 6025Z, as it has good magnetic properties. Based on Widyaningrum's summary (2014), superiority of vitrovac is having high permeability, ($\mu r \sim 10^5$), saturated by magnetic induction about 0.58 T, having low coercivity and power dissipation, high temperature stability and more resistant to external mechanical influences [6].

There are two types of circuit work in the analog signal processing circuit namely excitation circuit which generates reference magnetic field and pick up circuit that converts magnetic field to electric signal which was represent by external magnetic field.

Fluxgate needs to be characterized in order to get information about fluxgate characteristic using calibrator coil. Calibrator coil used in this study is a solenoid with diameter about 4 cm, consist of 600 windings of wire that had diameter about 0.7 mm. Characterization performed in Faraday cage, with sensor was placed in the calibrator that was positioned parallel to the direction of the east - west of the earth to reduce the influence of Earth's magnetic field on the measurement results. Then, the calibrator was energized by DC current in the range of 0.01 - 20 mA to get a magnetic field value according to eq. 1 [4].

$$B(I) = 1.9568 \cdot I - 0.0347 \tag{1}$$

The next step was distance calibration of sensor, the distance between magnet source and sensor were changed in micrometer order, this change makes output voltage of sensor changes too. So this process was obtained connection the distance to magnetic field that is represented by the output voltage. Next action is mass calibration, it is aim to get connection between the change of mass to sensor output with

Figure 4: Standard loads that used in mass calibration.

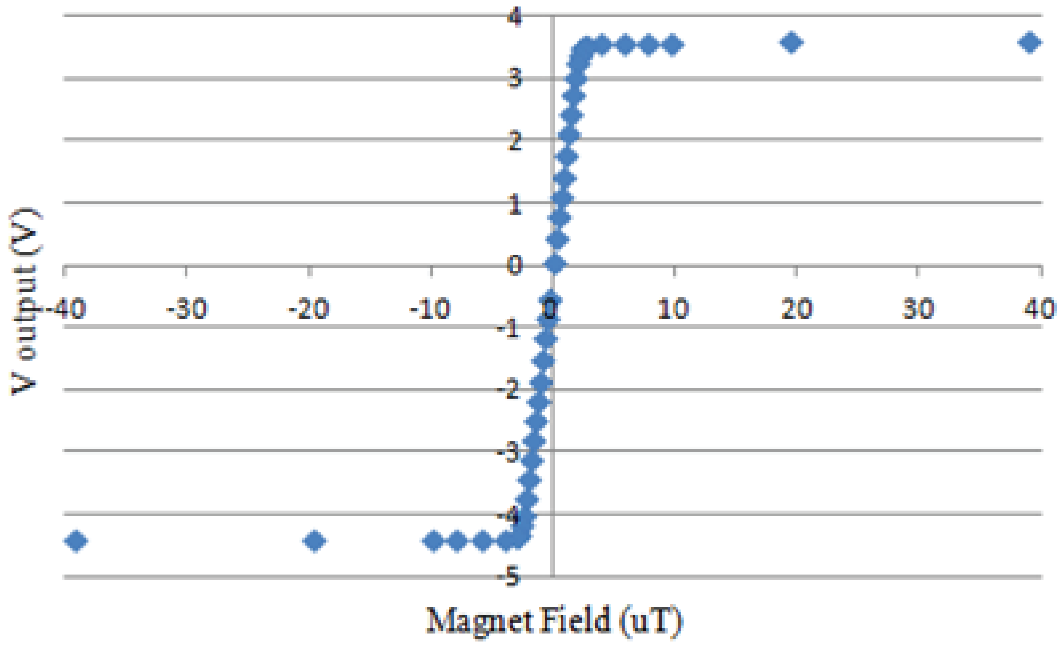

Figure 5: Hysteresis curve.

mass changes each 10 gram. Mass that was used is standard loads as shown in Figure 4.

The output of the signal processing circuit was analog voltage, and then it was converted to digital using microcontroller Arduino uno Atmega328. The result of mass measurement will be displayed on LCD 1602A which consist of 16 columns and 2 rows.

3. Result and Discussion

Fluxgate sensor was fabricated using conventional techniques with configuration 360 winding of excitations and 240 winding of pickup, having vitrovac 6025Z type core. Hysteresis curve as shown in Figure 5 obtained by characterization using calibrator coil, where magnet field value was obtained by Eq. 1.

Figure 6 explain that the core is saturated by magnetic field at $\pm$ 2.7 μT, shown that the output will be constant although the current was increased.

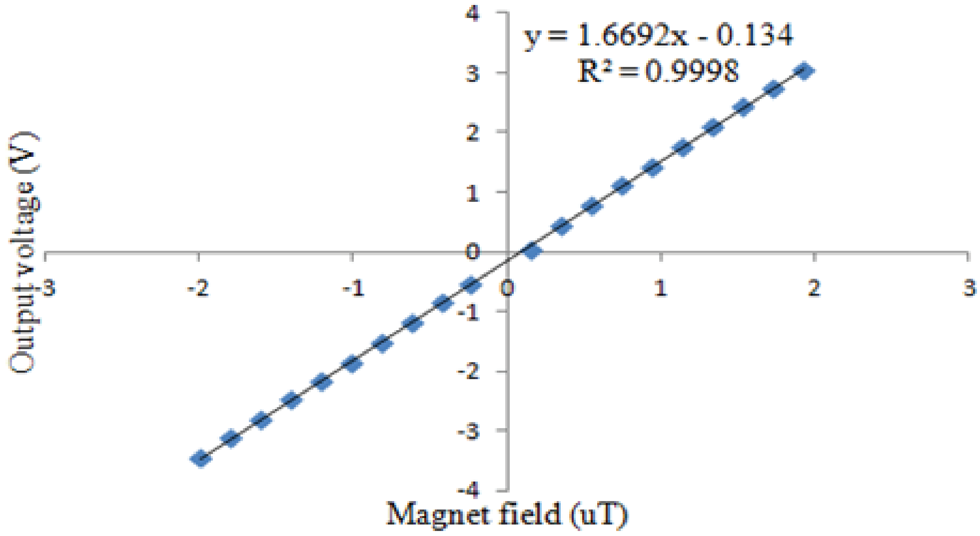

Figure 6: Graph of linear sensor in range ± 1.9 μT.

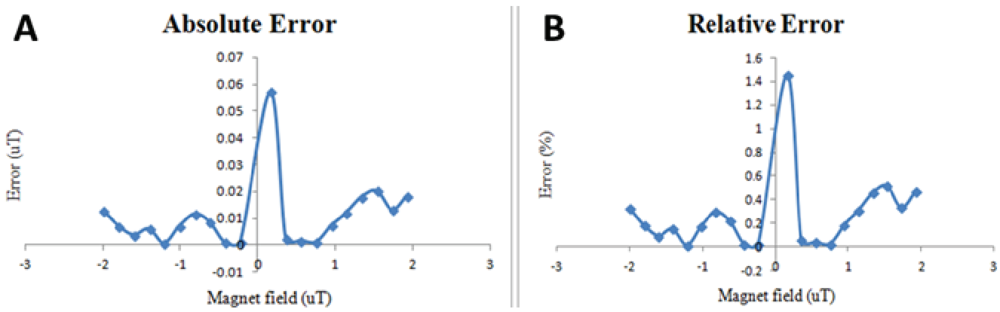

Figure 7: Error of sensor at range 1.9 μT.

The linear area from hysteresis curve is shown fig 8, explains that the sensor works in a range of ± 1.9 μT with linear equation (Eq. 2) that connecting output voltage (volts) to magnetic field (μT) on the work area.

$$V_o = 1.6692B - 0.134 \quad (2)$$

Eq. 2 reveals sensitivity sensor obtained was about 1.6692 V/μT or 1669.2 mV/μT and resolution sensor was found to be depending on the output voltage (Eq. 3) with R^2 value of 0.9991.

$$B(V_o) = 0.599V_o + 0.0803 \quad (3)$$

Absolute error of sensor is difference which is obtained by comparing result of magnetic field calculation in eq. 1 and result of measurement in eq. 3, as shown in fig. 7. The maximum absolute error obtained is 0.0573 μT (a) and maximum relative error sensor is 1.464% (b) at magnetic field of 0.161 μT, due to the magnetic field measured was very weak.

The result of calibration sensor to distance was shown in fig. 8, explains the working area of sensor at a range of 15.85 to 27.00 mm. In this range, the smaller distance

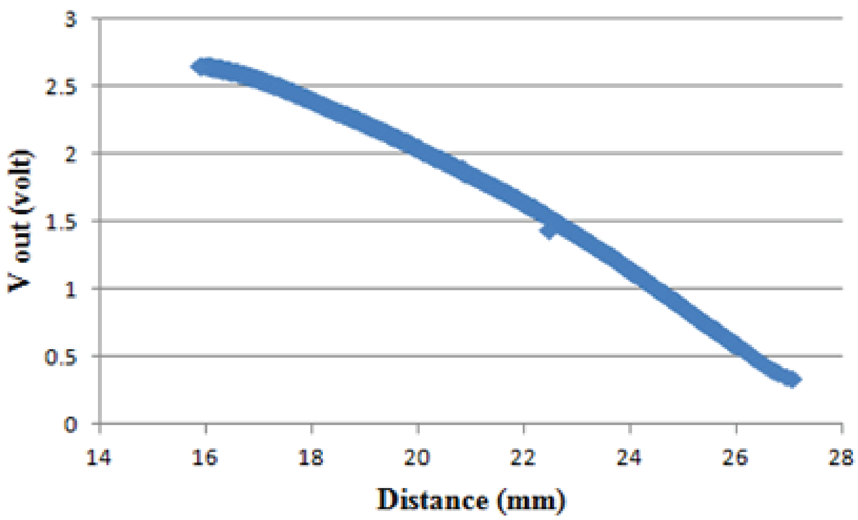

Figure 8: Graph of sensor calibration to distance.

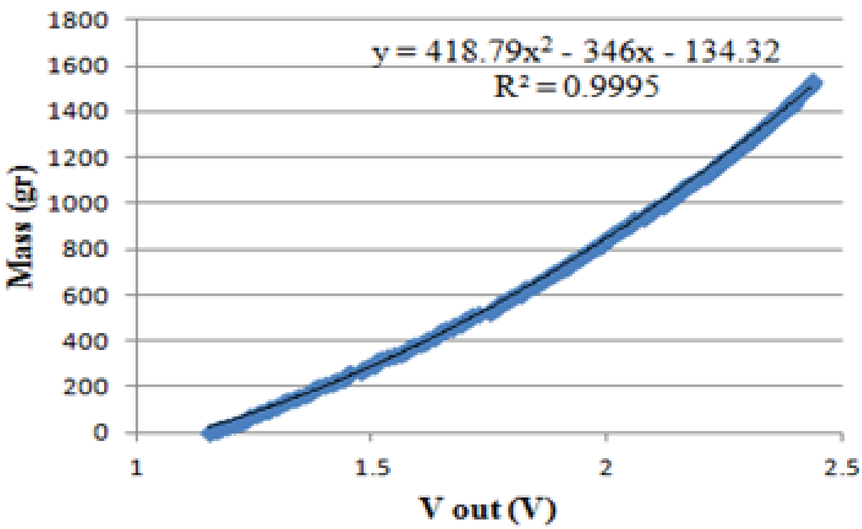

Figure 9: Mass value depends on output voltage.

between sensor and magnet, the bigger voltage output sensor that represents the measured magnet field. This result was then used to determine the distance between sensor and magnet on the scale.

To determine the mass of the measurement results, we need to use the function of the mass to the output voltage curve approach as shown in Figure 9 that is obtained by mass calibration.

From this curve with polynomial approach, we got the mass function that depends on output voltage (Eq. 4). This equation will be inserted into microcontroller as the mass of measurement results of scale.

$$m(V_o) = 418.79\,V_o^2 - 346V_o - 134.32 \tag{4}$$

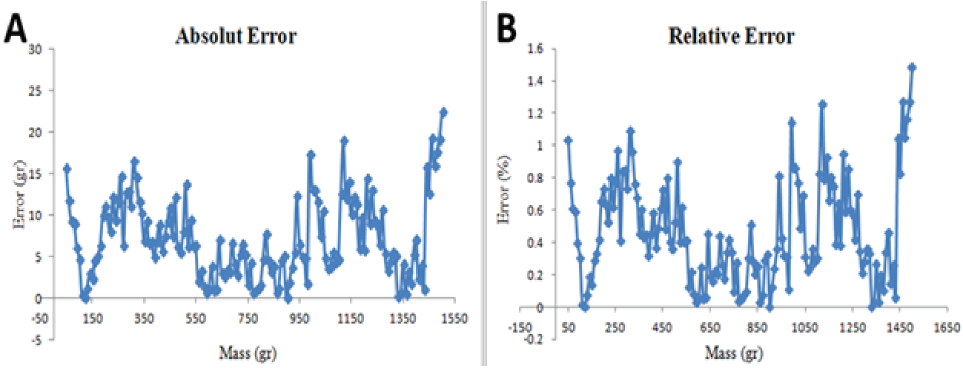

Figure 10: Absolute and relative error of digital scale.

By comparing the mass of the equation 4 with the actual mass, there is difference that is called absolute error. The maximum absolute error is 22.4 gram at measurement of mass about 1500 gram (fig. 10), and the maximum relative error is 1.49%. It also shows that the range that can be measured by the scale obtained are from 50 - 1500 gram.

4. Conclusion

Fluxgate sensor as magnetometer measures the magnetic field by comparing the measured magnetic field with the magnetic field reference. This type of sensor was successfully developed and applied in digital scales. Fluxgate sensor developed by conventional techniques, consisting of 360 excitation coils and 240 pick-ups coils with the ferromagnetic core use is Vitrovac 6025Z type. This sensor with a sensitivity of 1669.2 mV/uT, resolution 0.5991 uT/V, working in the range $\pm$ 1.9 μT, having the maximum absolute error of 0.0573 μT and the maximum relative error of 1.464%. The sensor works very well at a range 15.86 to 27 mm, thus the distance between the source magnet and sensors was regulated in this range. The maximum error absolute of scale is 22.4 gram and relative error is 1.49%. Range of mass measurement of digital scale are 50 – 1500 gram.

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