Sensors and Actuators A 151 (2009) 141–144

Contents lists available at ScienceDirect

Sensors and Actuators A: Physical

journal homepage: www.elsevier.com/locate/sna

PCB sensors in fluxgate magnetometer with controlled excitation

Michal Janošek*, Pavel Ripka

Czech Technical University in Prague, Faculty of Electrical Engineering, Dept. of Measurement, Technická 2, 166 27 Prague, Czech Republic

ARTICLE INFO

Article history:
Received 28 April 2008
Received in revised form
23 December 2008
Accepted 16 February 2009
Available online 28 February 2009

Keywords:
Fluxgate sensor
PCB technology
Controlled excitation

ABSTRACT

A miniature fluxgate sensor with amorphous race-track core manufactured with printed circuit board (PCB) technology is presented in this paper. The number of PCB layers was increased to five; this allowed for increasing the number of turns of pickup/compensating winding (68), resulting in the compensation current in the feedback loop below 15 mA for a 50 μT measured field. The sensor was characterized using pulse excitation (10 kHz, 10% duty); the maximum sensitivity was found to be 615 V/T for 650 mA p–p excitation current with nonlinearity below 0.5% of full scale. In order to improve the long-term and temperature stability of the sensor, a closed-loop regulation of the excitation current amplitude was designed. A three-axial portable magnetometer using gated integrators and pulse excitation was constructed with these sensors. Feedback-loop operation allowed suppressing the nonlinearity below 100 ppm of ±50 μT full-scale, and the sensitivity increased to 120,000 V/T. Long-term stability was found to be 1 nT in 9-h period, and the temperature coefficient of sensitivity decreased to 50 ppm, which was a direct result of controlling the excitation current.

© 2009 Elsevier B.V. All rights reserved.

1. Introduction

Printed circuit board (PCB) technology in fluxgate sensors, as introduced in [1], brings the following benefits: stability of the sensor's parameters (as there are no wound or moving parts), low dimensional demands, and ease of mass-production. The progress in PCB fluxgate sensors clearly shows that the limitation in their parameters is the low number of turns of the coils created by PCB technology. For an excitation coil, this problem can be solved using a pulse excitation current, which allows for effectively decreasing power dissipation while still maintaining sufficient saturation of the core. As for the pickup coil, the coil constant determines not only the sensitivity of the sensor, but it also determines – when used as a feedback coil – the power dissipation in compensating mode, which practically limits its usability.

2. Development of PCB fluxgate sensor 'IIIA'

In previous work, as done by Kubik et al. [2,3], miniature sensors with a race-track core of the amorphous material Vitrovac 6025X were made using a three-layer PCB technology, with excitation and pickup coils formed by copper track connected by electroplated through-hole vias. Compared to micro-sized designs with planar coils [4], this sensor allowed us to use much lower excitation frequencies. The number of turns of the pickup coils was low, which limited their performance.

The new sensor IIIA was designed to use five PCB layers; the pickup coil is formed by the copper tracks on the top and bottom layers (Fig. 1: 4 and 5), and the excitation coil consists of tracks on two middle layers (Fig. 1: 1 and 3). Technologically, the inner part was laminated in the first phase; in the second step this sub-PCB was laminated between the top and bottom layers. The etched race-track core of 25 μm thick material is laminated in a machined bobbin in the middle. The dimensions of the sensor are 33.5 mm × 15.6 mm × 0.9 mm.

When compared to the previous sensor type IIA with a similar design but only three PCB layers [5], the number of turns of pickup winding was increased from 20 to 68; thus the compensating current for the 50 μT measured field decreased from 46 mA to 14.5 mA. The pickup winding resistance increased to 4.9 Ω due to the increased number of electroplated holes; this determines power loss in the winding (1 mW for 50 μT). Both sensors are shown in Fig. 2.

3. Pulse excitation unit with amplitude stabilization

Pulse excitation is used because of lower power consumption. It has been observed that the offset and sensitivity parameters of sensor IIIA depend on the amplitude stability of the excitation current. This could be caused by asymmetry of the sensor (varying thickness of the amorphous layer, misalignment of the pickup or excitation coil respectively), and by the possible presence of even harmonics

* Corresponding author. Tel.: +420 22435 3964.
E-mail address: janosem@fel.cvut.cz (M. Janošek).

0924-4247/$ – see front matter © 2009 Elsevier B.V. All rights reserved.
doi:10.1016/j.sna.2009.02.002

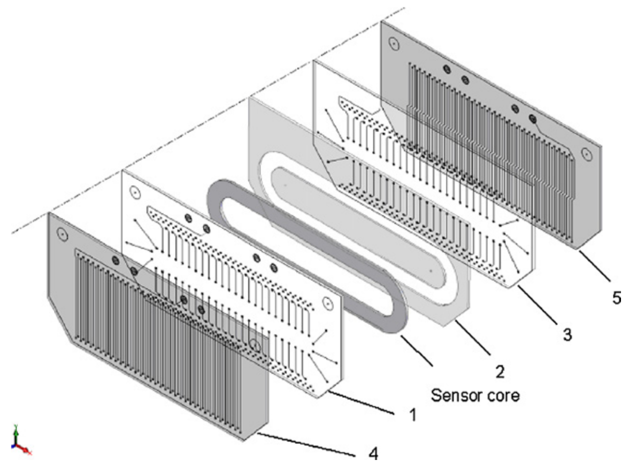

Fig. 1. Sensor IIIA construction—sensor core with its bobbin (2), layers forming excitation coil (1 and 3) and pickup coil layers (4 and 5).

in the excitation current (due to unmatched bridge resistances). A feedback circuit was designed in order to stabilize the amplitude of the current peaks caused by the temperature drift of the resistance of the excitation winding or of the MOSFET switches.

A block diagram of the excitation unit is shown in Fig. 3. Driving pulses for the full H-bridge are provided by decoding three PWM outputs of the PIC16F737 microcontroller. The excitation current is sampled with a peak detector and a PI-regulator drives the reference setting of the DC/DC converter, whose output is the bridge voltage V_{br}. The desired reference setting is provided by a D/A converter of the microcontroller.

The sensor's sensitivity, linearity and offset have been measured with a lock-in amplifier SR-830 referenced to the second harmonic of excitation current. The results, as shown in Fig. 4, indicate the largest sensitivity for 650 mA p–p excitation current. However, the sensor's offset increases only marginally with the excitation current (4 nT change for 500 mA excitation current change, not shown in Fig. 4).

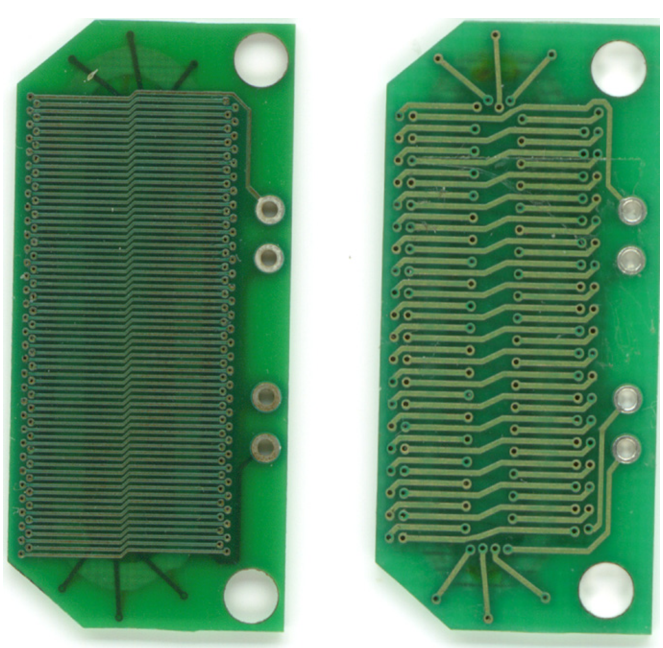

Fig. 2. Sensor IIIA (left) and the old design IIA (right) for comparison.

Table 1
Overview of magnetometer's sensitivities and nonlinearities.

Axis	X	Y	Z
Sensitivity - vector cal.[V/T]	106,757	104,413	106,562
Sensitivity - scalar cal. [V/T]	119,952	117,107	119,491
Offset [nT] - from scalar cal.	−1,048	−257	68
Axes non-orthogonalities [″]	1,345.4	485.2	4,936.5
Nonlinearity [ppm of FS]	65	60	93

4. Feedback-loop operation in a magnetometer

A battery powered three-axis magnetometer unit was constructed, with a triaxial sensor holder, which was connected to the body of the magnetometer directly or with a cable. A pulse excitation unit with controlled and amplitude-stabilized excitation current was used according to Fig. 3, and the output signal was processed with the use of gated integrators [5]. All of the following measurements were done with an excitation current of 450 mA p–p, which was found to be the best compromise, with a frequency of 10 kHz and a 10% duty cycle.

4.1. Sensitivity, linearity parameters

Sensitivity was measured using a simple vectorial calibration in Helmholtz coils; later a scalar calibration (implemented after Olsen et al. [6]) was performed in a magnetically quiet location and referenced to the reading of an Overhauser magnetometer. The RMS error of the calibration was 9 nT. Linearity of the magnetometer was determined by averaging multiple runs of sensitivity measurements in Helmholtz coils, covering the whole full scale of ±50 μT. The results are summarized in Table 1. There is an indication of scale error of the vectorial calibration, as the ratio of the sensitivities is the same for both methods. When the sensor triplet was connected to the magnetometer's body, sensitivities changed by +0.8%, +1.1% and +1.4% for the *X*, *Y* and *Z* axes, respectively. This is believed to be an effect of compensation flux leakage due to the magnetometer body. Also, the offset of the *Z*-axis increased to 650 nT (influence of built-in accumulators and magnetometer electronics).

4.2. Offset stability in the feedback loop

Offset stability was measured using six-layer Permalloy cylindrical shielding, with electronics kept in a temperature-stable place; the sensor temperature varied by ±1 °C. The influence of the excitation amplitude on the offset stability was evaluated: larger excitation currents exhibited larger offset drift due to the sensor's self-heating. As the best result, an excitation current of 450 mA was chosen for operation in the magnetometer. Long-term measurements resulted in an offset stability of 1 nT in 9 h (Fig. 5), with approximately 1 nT p–p short-time change (ultra-low-frequency noise), which is superior to the 3.7 nT stability of sensor IIA previously achieved in [5]. When the stabilization circuitry was disabled, the offset stability worsened to 4 nT in 9 h and the ultralow-frequency noise increased to 2 nT p–p.

4.3. Temperature stability

Temperature stability was measured separately in order to evaluate the influence of the sensor and electronics. The sensor (or the magnetometer electronics) was temperature cycled within 70 °C change, and the stability was then determined in the working range of 10–45 °C (Table 2).

The stabilizing circuitry was also disabled to determine the change in parameters: the influence of the electronics was basically the same, but the sensor influence to sensitivity drift worsened to

Download English Version:

https://daneshyari.com/en/article/740262

Download Persian Version:

https://daneshyari.com/article/740262

Daneshyari.com