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Design of a DC Current Sensor Based on Fluxgate Principle

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Article

Precise DC current measurement has been one of the important topics of metrology science as a result of technological developments in diverse sectors of the industry, e. g. nanotechnology. In order to measure DC current, different techniques based on various working principles have been developed. Those are well described in references . On the other hand, these current sensors have an accuracy of between 0.5 and 2%. According to Ripka et al, high-precision measurement of DC current can be ensured by using fluxgate principle . In the present work a current sensor based on fluxgate principle was designed for the measurement of small DC currents. It consists of two coils wound on toroidal ring core from cobalt-based amorphous Metglass 2714A ribbon. The inner primary coil was driven by proper excitation signal and the magnitude of the second-harmonic voltage (2f signal) induced by the outer secondary coil was evaluated to be the sensor signal. The DC current in a wire inserted through the center of the toroid was measured as independent variable. The results presented in the paper show that a good linear relation between the magnitude of the DC current and the 2f signal can be achieved. 2. EXPERIMENTAL PART The sensor shown in consists of two coils, primary and secondary, used for excitation and signal detection, respectively. The core of the sensor consists of 10 turns of amorphous ribbon wound on polyether ether ketone (PEEK) support having a diameter of 10 mm . The material of the core is from Metglas 2714A ribbon with a thickness of 15 μm and width of approximately 3.2 mm. The excitation coil consisting of 135 turns of a 200 μm diameter copper wire was wound uniformly over the entire circumference of the toroid. The detection (pick-up) coil having 260 turns was wound on top of the primary coil in a similar manner using a copper wire of 100 μm diameter. The measured DC current was passed through a 700 μm diameter copper wire was used to carry the measured DC current through the center of the toroid. The dependence of the magnitude of the second harmonic of voltage induced in the secondary (pick-up) coil, V2f, on excitation frequency Applied Physics of Condensed Matter (APCOM 2019) AIP Conf. Proc. 2131, 020007-1–020007-3; https://doi.org/10.1063/1.5119460 Published by AIP Publishing. 978-0-7354-1873-8/$30.00 020007-1 fex was determined at different frequencies. For each excitation frequency selected scale factors were determined by measuring the magnitude of V2f for ± 100 mA DC current range . In addition, noise analyses were performed. The second harmonic measurements of V2f were carried out using SR830 Lock-In Amplifier. The noise analysis was carried out with a dynamic spectrum analyzer Agilent 35670A in a triple mu-metal shield.. The preparation of the current sensor; bare ribbon core shown in top left part of the RESULT AND DISCUSSION The characterization of the current sensor was started with determination of optimal excitation frequency. For this purpose, a constant DC current was driven to the wire passing through the center of the sensor. The 2f signal was recorded with the span of excitation frequency ranging from 20 kHz to 50 kHz with 10 Hz intervals. As seen from Figure 2a, there are two minor (22.40 kHz and 26.00 kHz) and one major peak (32.04 kHz) on the 2f signal. Scale factor measurements were carried out at these frequencies. As seen from Figure 2, the highest scale factor was observed at 32.04 kHz with magnitude of 182 mV/A. It was determined to be 149 mV/A and 127 mV/A for 26 kHz and 22.4 kHz, respectively. It is also clearly seen that there is quite high linear dependence between the measured DC current and 2f signal induced in the pick-up coil. The correlation coefficient of the linear fit between DC current and 2f signal has a value R 2 better than 0.99, which confirms the agreement of experimental data with the linear fit. Finally, noise analyses were carried out in a three layer u-metal chamber for the selected excitation frequencies. The noise values at 1 Hz were determined to be 0.77 mA/√Hz, 46 μA/√Hz and 59 μA /√Hz for the frequencies of 32 kHz, 26 kHz and 22 kHz, respectively. From the noise analyses it is understood that although the scale factor is highest at excitation frequency of 32 kHz, it is the worst one from the noise viewpoint. The lowest noise value was obtained for excitation frequency of 26 kHz. At this excitation frequency it was possible to resolve DC currents as low as 60 µA. We believe that both the scale factor and noise levels of the studied current sensors may be optimized further in a simple and inexpensive way by additional tuning of the sensor circuits such as connecting additional serial resistance and parallel capacitor to both excitation circuit and pick-up circuits . It will be a subject of our future studies. 020007-2 (a) The second harmonic signal as a function of excitation frequency. (b) Scale factor measurement for different excitation frequencies. (c) Noise measurements at different excitation frequencies. In this study the effects of the excitation frequency and noise on the sensitivity of DC current sensor based on fluxgate principle were investigated. We prepared the current sensor consisting of two coils wound around toroidal ring core from cobalt-based amorphous Metglass 2714A ribbon. Optimization studies for the excitation frequency and noise analyses were done. It was possible to sense DC currents in the range of ± 100 mA with the resolution as high as 60 µA using the optimized excitation frequency. The scale factor (sensitivity) and noise levels of the studied current sensors may be further optimized by additional tuning of the sensor circuits This work was supported in part by the Scientific and Technological Research Council of Turkey (TÜBİTAK) under grant 118F012 and in part by the Slovak Academy of Sciences under the SAV-TUBITAK JRP grant MAGSAT.

Biography:

Eylem Coker is a professor in Cambridge Graphene Centre, and studied in University of Cambridge, Cambridge UK.In 2016, he also joined the Institute Of Integrated Nanoscience and left in 2018 and recently he is working related to frequency.

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